Evaluation of Energy Efficient Design Competition of a Public Office Building in North Greece

by

ASIMINA CHATZIMANOLI

The Bartlett School of Graduate Studies
University College London

A Dissertation submitted in part fulfilment of the
Degree of Master of Science Built Environment:
Environmental Design and Engineering

University of London
September 15, 2005

Word count: 12,148

To my mother

ACKNOWLEDGEMENTS

I would like to express my gratitude to the following, who contributed to this report in various ways:

Dr. Ben Croxford, from the Bartlett School of Graduate Studies, who supervised this report, for his guidance, encouragement and patience in the whole report-making process.

Dr. Alan Young, from the Bartlett School of Graduate Studies, for giving me the opportunity to participate in the Environmental Design and Engineering MSc course in the Bartlett School of Graduate Studies.

Professor Niobe Chrysomallidou, from the Aristotle University of Thessaloniki, Greece, Department of Civil Engineering, who kindly agreed to meet me and discuss issues of the report, for the valuable data she provided, without which this work would not have been completed.

Dr. Ryan Southall, Visiting Lecturer at the Bartlett School of Graduate Studies, for his valuable comments and suggestions on the report.

I am also grateful to **all the Officers of the Police Station of Kilkis**, who kindly allowed me to visit and monitor the building. Without their permission to survey the building this report would not have been carried out. I would like to note that any plans of the building used in this report were provided by the Department of Urban Planning, Prefecture of Kilkis.

ABSTRACT

Over the past few years in Greece there have been changes in the National Environmental and Energy Policy related to sustainability and energy conservation-saving, concerning the built environment as well. In this context, in 1999, the Hellenic Public Real Estate Corporation announced a Public Open Competition for the "Design and Construction" of a Police Station in the city of Kilkis, in North Greece. The energy efficiency and bioclimatic design was part of the General Design Principles of the brief.

The following Report aims at evaluating the energy performance of the building and the comfort levels in the internal environment and determining the benefits of incorporating environmental design in a Public Office Building, in terms of savings in the energy consumption for heating.

The Methodology included a description of the features of the design, analysis of the differences between the initial design and the constructed building, investigation of the operation of the constructed building (monitoring, questionnaire survey, energy consumption) and evaluation of the effect of the differences mentioned, using computer simulation (TAS software).

Internal Temperatures fluctuated less than the external but for most of the monitoring period (end of mid-season-beginning of summer) Maximum Temperatures were higher than the external. The occupants gave positive comments and evaluated the general working conditions in the building as good, but the majority were not aware of the Passive Solar Systems installed in the building. The actual energy consumption for heating (150.85kWh/m^2) is approximately 85% of the average consumption of Public Office Buildings in North Greece but 50% higher than that of recently built Public Office Buildings. However, the figure from the simulation analysis (corresponding to Office and Common spaces) is approximately 1/3 of the actual (55.14 kWh/m^2), suggesting that proper operation of the building could result in significant reduction in energy required for heating.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. PREFACE

Over the past few years in Greece there have been changes in the National Environmental and Energy Policy with new Strategies, Regulations and Economic Measures related to sustainability and energy conservation-saving. In terms of the built environment, accounting for 30% approximately of the National energy consumption and 40% of CO_2 emissions [1], the strategic plan "Energy 2001" was carried out in 1996 by the Ministry for the Environment, Physical Planning and Public Works in collaboration with other Institutes and Research Centers [2]. Specific strategies and measures concerning the energy saving in existing and new buildings were incorporated. Apart from technical specifications, it is stated that Competitions and Awards can become important strategies towards the improvement of the energy performance of buildings and towards successful bioclimatic designs of buildings and urban complexes [3].

In this context, in 1999, the Hellenic Public Real Estate Corporation announced a Public Open Competition for the "Design and Construction" of a Police Station in the city of Kilkis, in North Greece.

The energy efficiency and bioclimatic design was part of the General Design Principles of the brief [4]. According to the relevant section, it is stated that the energy demands of the building should be determined and that there should be provision for utilization of natural environmental conditions for achieving a comfortable internal environment. [5] The building should be integrated into the local environment and climate conditions in a way that the annual energy demands are minimized and the consumption of conventional types of energy is reduced [6].

In order to achieve thermal comfort throughout the year, the heating and cooling loads should be reduced and passive heating and cooling should be incorporated [7]. The shape of the building should be as compact as possible with increased insulation, so as to reduce these loads.

In terms of passive design, South orientation should be utilized as much as possible, while large openings towards the North should be kept to minimum [8].

The running cost of the building was an important parameter as well. It was noted that the integration of the building into the local environmental conditions and the incorporation of passive heating and cooling strategies would contribute to achieving a reduced running cost [9].

In terms of lighting, the design should aim at the maximum utilisation of natural light in the office spaces [10].

The results of the Competition were announced in April 1999 and the final design (architectural, structural, electrical, mechanical) was approved in April 2000 (Appendix A). The new building was occupied in December 2001.

In the following paragraph the basic aims and objectives of this Report are set out.

1.2. AIMS AND OBJECTIVES

The Report aims at evaluating the energy performance of the building and the comfort levels in the internal environment and determining the benefits of incorporating environmental design in a Public Office Building.

More specifically, since the significant proportion of energy consumption of Public Office Buildings in Greece corresponds to the energy consumption for heating, [11] the extent to which passive systems contribute to energy saving will be investigated. In addition, the contribution of different strategies of the design will be discussed.

Apart from the energy consumption, this Report will evaluate the internal environmental conditions and comfort levels in the building using monitoring and also occupants evaluation.

Finally, the performance of the building will be compared to that of similar Public Office Buildings in Greece, in order to investigate if the incorporation of bioclimatic design in Public Buildings Briefs can contribute to the reduction of energy consumption.

1.3. METHODOLOGY AND STRUCTURE OF THE REPORT

The design of the Police Station and the different strategies applied within the context of bioclimatic design are analyzed and discussed. A literature review provides background knowledge related to the basic Passive Solar System of the building.

There were differences between the initial design and the constructed building and the report will attempt to evaluate the effect of these differences on the buildings performance.

In order to evaluate the internal conditions, the building was surveyed during mid May-mid June 2005 (17.05.05-10.06.05). Data from monitoring (Temperature-Relative Humidity) during the period mentioned above is analyzed. In addition, the results of a survey on occupants carried out on a typical weekday, give an indication of the occupants evaluation of the building and its internal environmental conditions.

The energy consumption for heating of the last year (2004-2005) will be used to compare the performance of the new building of the Police Station of Kilkis with that of other Public Office Buildings of the prefecture of Central Macedonia, North Greece, including the old building of the Police Station in Kilkis. The comparison is based on the results of the project "Renovation of the public buildings of Macedonia for the improvement of their energy performance" [1] [12].
Finally, the effect of the differences between the initial design and the constructed building will be evaluated using computer simulation and applying different scenarios.

Summarizing, the following Report is based on the following structure:

- Design analysis, Literature review of main bioclimatic feature
- Constructed building - differences
- Operation of constructed building: (occupants behaviour, internal conditions monitoring, questionnaire survey, energy consumption analysis)
- Simulations- evaluation of different scenarios
- Conclusions drawn

1. The project "Renovation of the public buildings of Macedonia for the improvement of their energy performance" was carried out by Domotechniki SA Public and Private Technical Projects, the Laboratory of Contruction and Building Physics of the Aristotle University of Thessaloniki and the Hellenic Public Real Estate Corporation and was funded by the program SAVE (Specific Actions for Vigorous Energy Efficiency) of the EU of 1994 [13].

REFERENCES

[1] http://www.minerv.gr/4/47/471/g47100.html [August, 2005]

[2] http://www.minerv.gr./1/13/132/13201g1320104.html [August, 2005]

[3] http://www.minenv.gr./1/13/132/13201g1320104.html [August, 2005]

[4] Hellenic Public Real Estate Corporation, *Competition Brief: Design and Construction of Police Station in Kilkis, 4. Description-Building Requirements*, Hellenic Public Real Estate Corporation, Athens, 1999, p.19,20
(original in Greek:
Κτηματική Εταιρία του Δημοσίου, Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς,Τεύχη Δημοπράτησης, 4. Περγραφή Αντικειμένου, Κτιριολογικό Πρόγραμμα, Κτηματική Εταιρία του Δημοσίου, Αθήνα, 1999)

[5] as [4], p.19

[6] as [4], p.19

[7] as [4], p.20

[8] as [4], p.20

[9] as [4], p.13

[10] as [4], p.18

[11] Liveris P., Aravantinos D., Papadopoulos A., Tsakiris N., *Guide of Energy Saving in Public Buildings*, European Commission- Directorate General XVII for Energy, Thessaloniki, 1996, p.17,18
(original in Greek:
Λιβέρης Πάνος, Αραβαντινός Δημήτρης, Παπαδόπουλος Άγις, Τσακίρης Νίκος, Οδηγός Εξοικονόμησης Ενέργειας στα Δημόσια Κτίρια, Ευρωπαϊκή Επιτροπή XVII Γενική Διεύθυνση Ενέργειας, Θεσσαλονίκη, 1996)

[12] as [11], p.12

[13], as [12], p.11-12

2. DESIGN

2.1. CLIMATE DATA

The city of Kilkis, where the building is located, is in North Greece (Latitude 41^0 [1]). As climate data for the specific location is not available, data for the closest cities Thessaloniki (Latitude $40^o33'$ [2]) and Serres (Latitude $41^o04'$ [3]) is given below[1].

Figures 2.1., 2.2, Maps of Greece and of the Prefecture of Central Macedonia

1. The climate data given for Thessaloniki is from the period 1936-1975 and for Serres from 1931-1940, 1956-1975. [4]

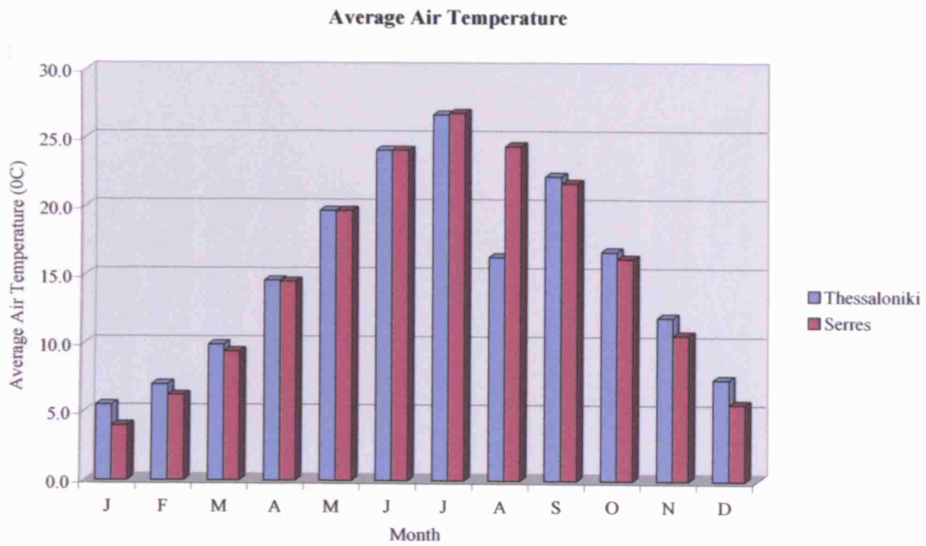


Figure 2.3. Average Air Temperature of Thessaloniki and Serres

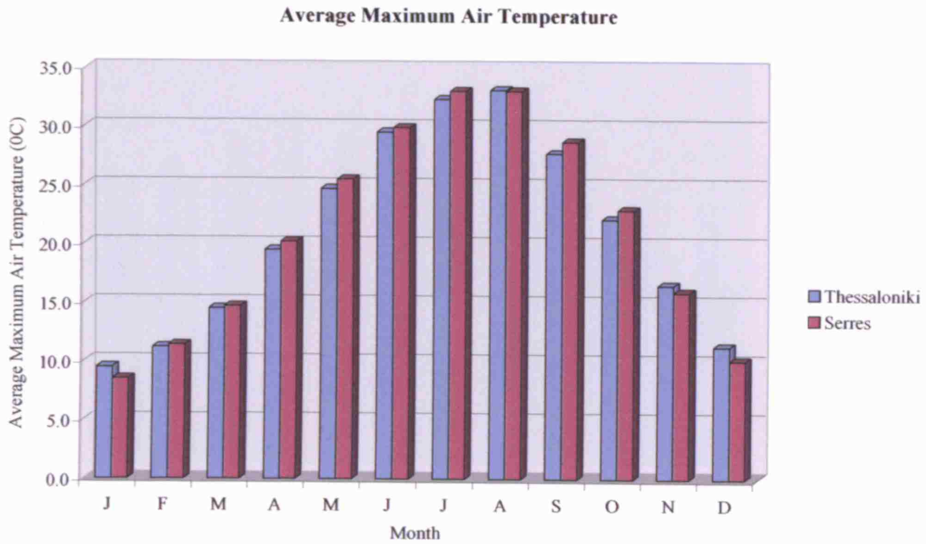


Figure 2.4. Average Maximum Air Temperature of Thessaloniki and Serres

Although average Temperature merely exceeds 25^0C, it can reach 32^0C in July and August. Predominant winds are from the North (Figure 2.7).

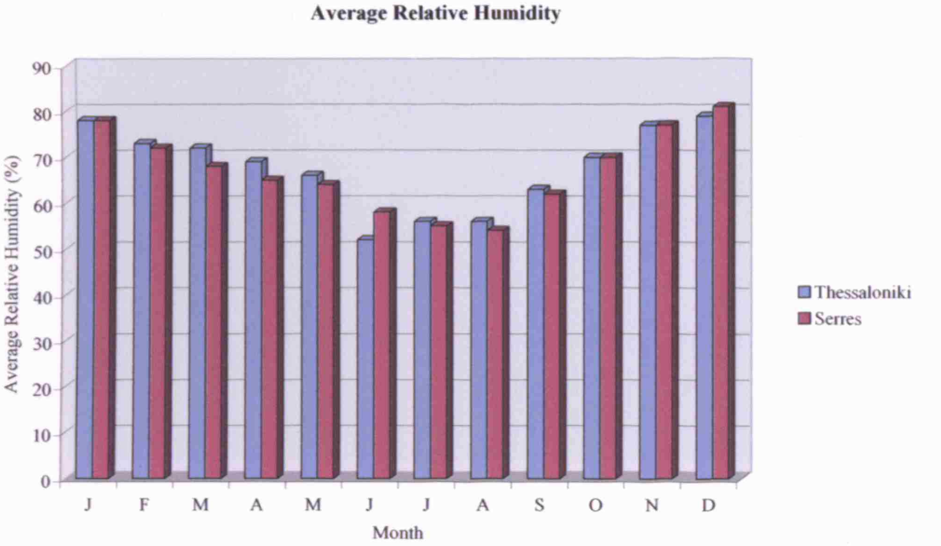


Figure 2.5. Average Relative Humidity of Thessaloniki and Serres

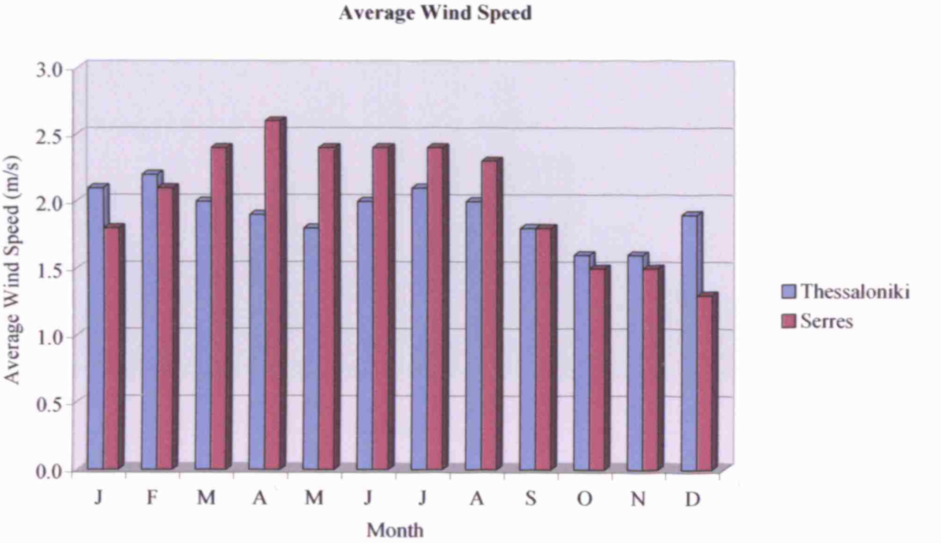


Figure 2.6. Average Wind Speed of Thessaloniki and Serres

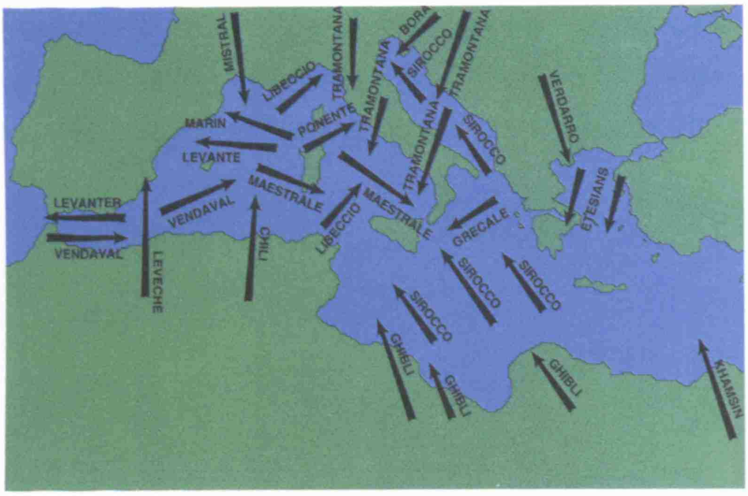


Figure 2.7. Predominant Winds of the Mediterranean Region

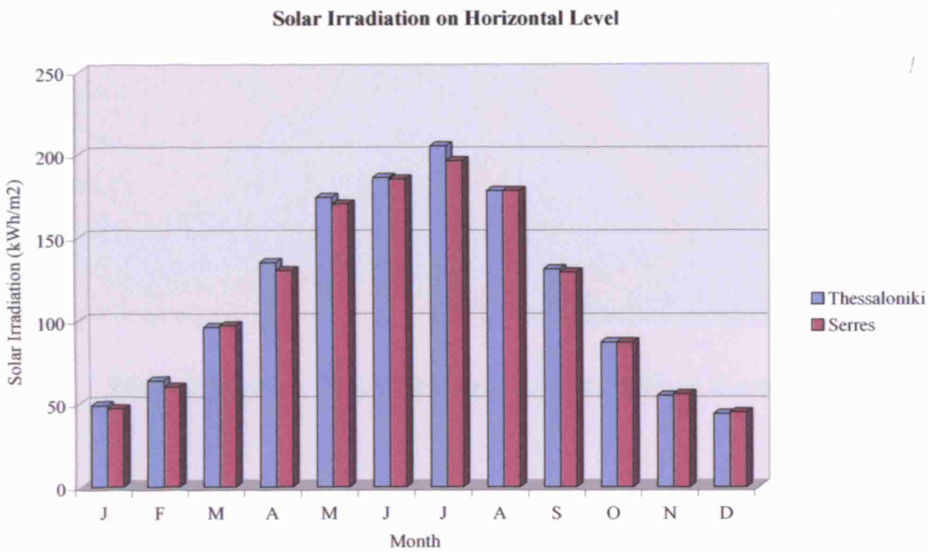


Figure 2.8. Solar Irradiation on Horizontal Level of Thessaloniki and Serres

The following graph allows for some comparison in terms of Solar Radiation. In the area of Kilkis the Annual Daily Solar Irradiation is approximately 4.2 kWh/m^2, similar to that of South France, while in London it is approximately 2.6 kWh/m^2.

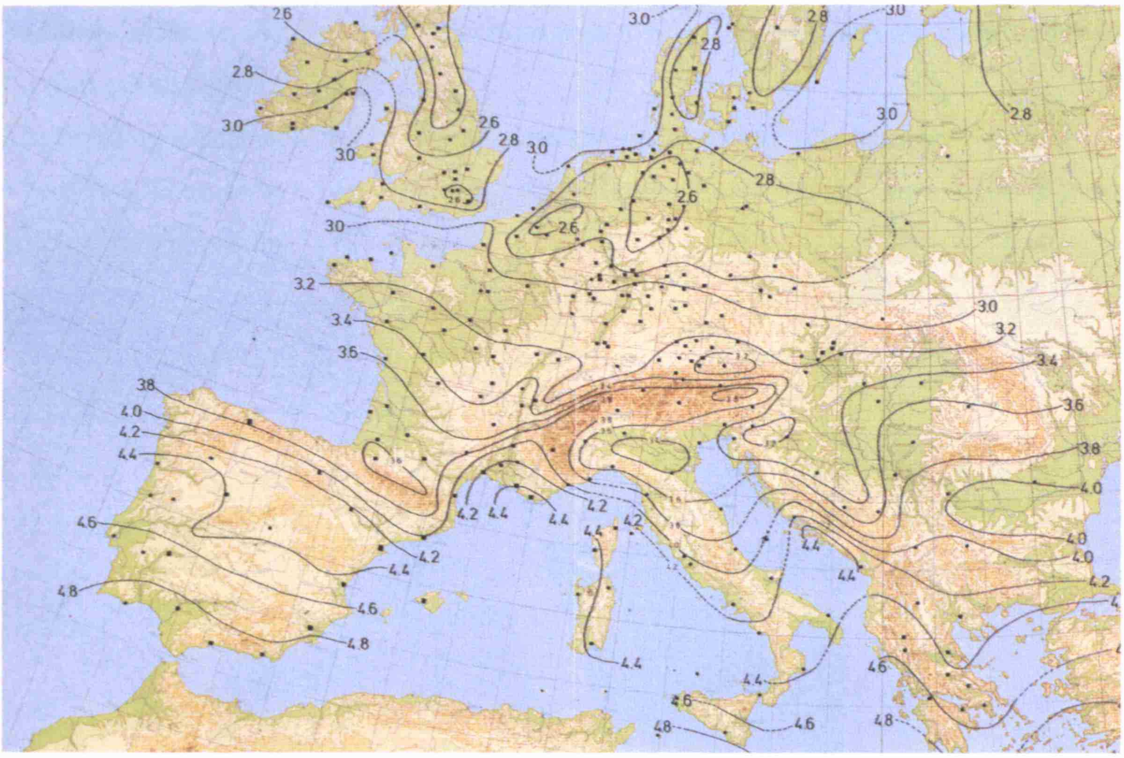


Figure 2.9. Annual Daily Global Irradiation (kWh/m^2) of Europe

2.2. SITE – BUILDING DESCRIPTION

The site (2360m^2) is in the outer urban zone of the city, where the maximum height of the buildings is 15.0m [5]. It is in a residential area, where few buildings are constructed so far (not a dense area).

The building is approximately 1890 m^2, with additional 850 m^2 of a basement space [6].

There is a slope on the east-west axis. The difference between the lowest and highest level of the site is 3.0m.

Figure 2.10. Site plan and adjacent buildings

In addition to the office spaces that occupy the greatest part of the building there are different types of spaces, according to the particular type of this public office building. Apart from an events-meeting space, a cafe, a gym and a shooting space there are rest rooms for the officers on duty and a flat for the Chief Superintendent, to be used when required. These are spaces with different requirements in terms of occupancy and thermal comfort. It was necessary to organize these spaces in zones according to these requirements and the different departments of the Police Station.

The building is developed in two volumes connected together with the basic circulation areas (stairs and elevators) and an atrium. The volumes are developed on an east-west axis and the whole volume is located on the northern edge of the site, in order to optimize its solar gains, ensuring adequate solar access [7].

The layout of spaces was arranged in order to have the minimum number of offices with North orientation possible. Temporary use spaces were located primarily in North oriented areas, in order to create a buffer zone for the rest of the building [8].

There are additional architectural features that serve environmental purposes as well, which are discussed in 2.4.

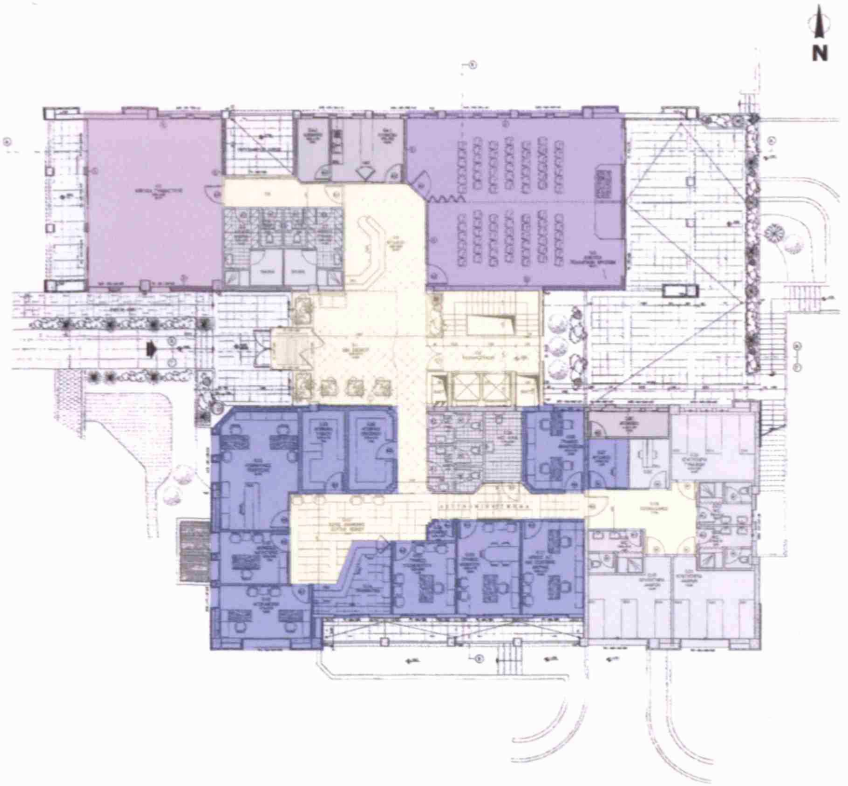


Figure 2.11 Ground Floor plan

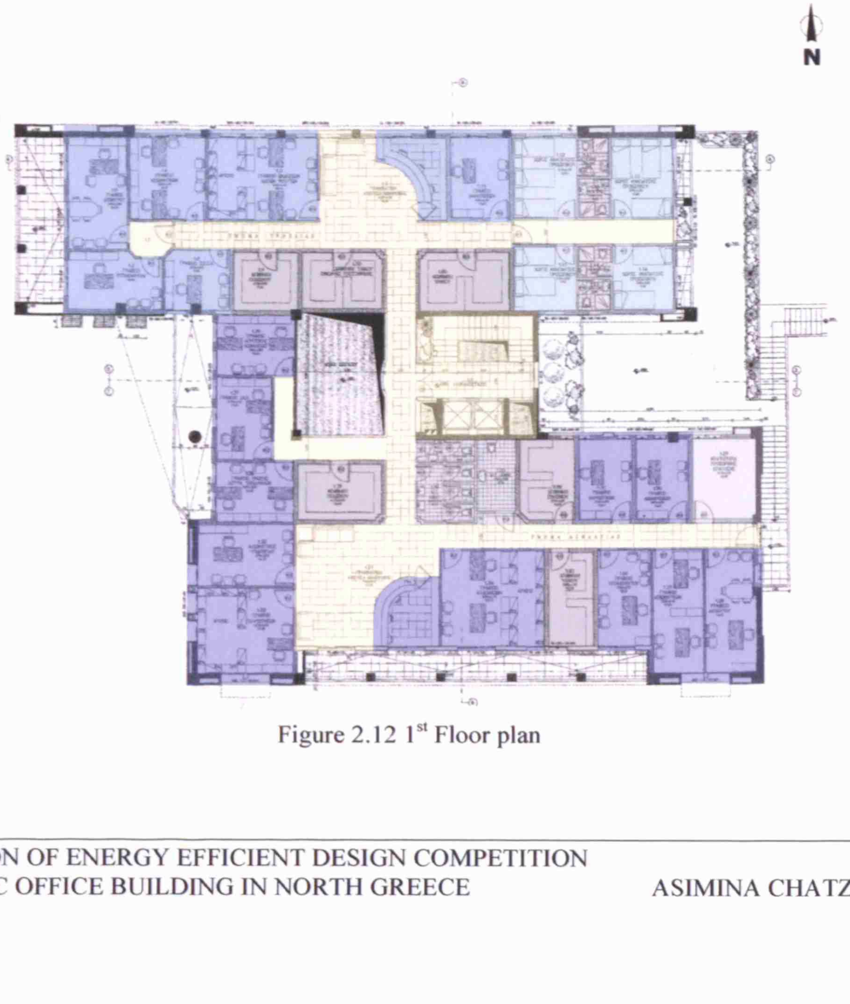


Figure 2.12 1st Floor plan

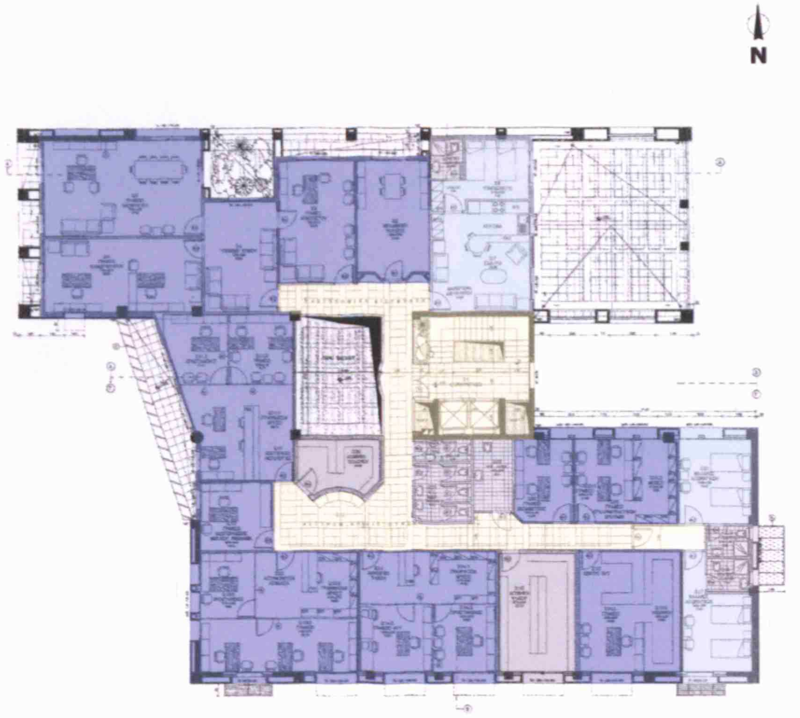


Figure 2.13. 2nd Floor plan

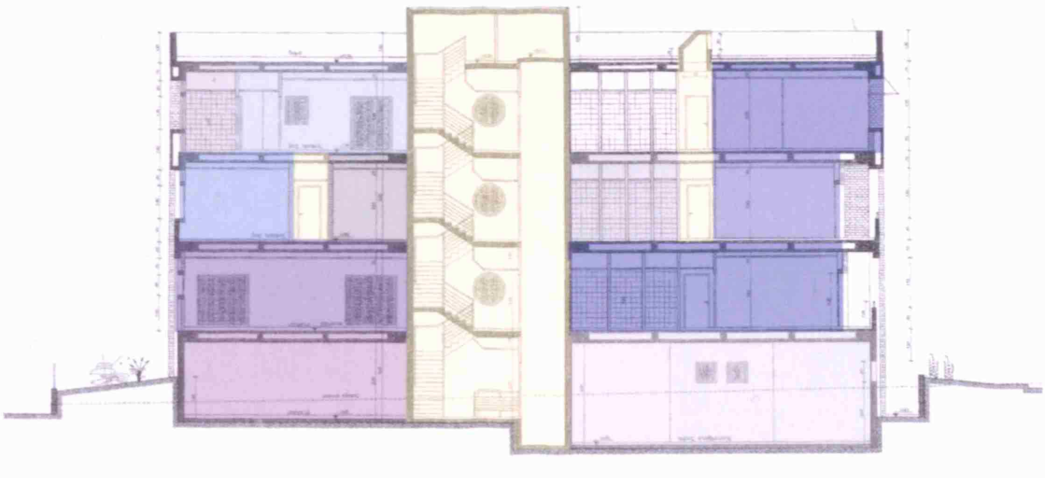


Figure 2.14. Cross-Section (N-S)

Figure 2.15 Longitudinal Section (E-W)

2.3. OCCUPANCY PATTERN

64 people work in the building but because of the particular type of the job, the offices are not occupied at all times. The typical working schedule is 7.30 am-3.30 pm. There are two offices that are occupied 24h/day, where the officers on duty are (Figure 2.16).

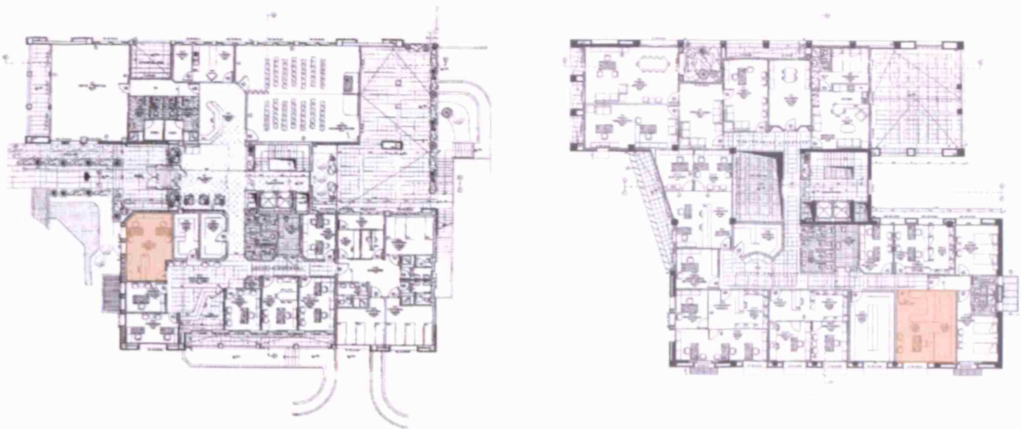


Figure 2.16. Offices occupied 24h/day

2.4. ENVIRONMENTAL STRATEGY

2.4.1. Passive Solar Systems – Analysis and Literature Review on Main Feature

2.4.1.1. Passive solar heating

The strategies for passive solar heating were selected based on the following criteria [9]:

- the occupancy pattern of the building (7.30 am-3.30 pm)
- simplicity in operation
- efficiency during both winter and summer period
- aesthetics
- the capital and maintenance cost

I. **Direct gains** in the office spaces of the South volume [10] through:

- windows and openings of the external wall
- clerestory windows over the corridor of the 2nd floor
- the atrium

It must be noted that the provision for shading provides unobstructed sun penetration during winter and rejection of solar radiation during summer.

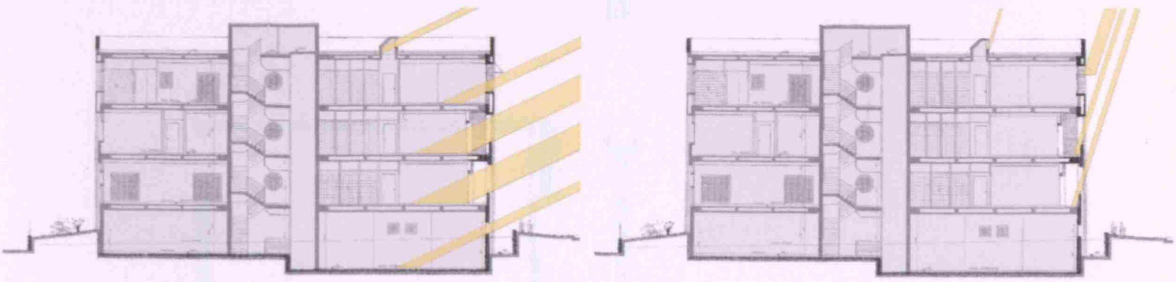


Figure 2.17. Direct gains in winter-Rejection of solar radiation in summer

II. Thermosyphon panels (TAP) on the external wall construction of the South elevation [11]

Figure 2.18. South Elevation illustrating the location of the TAPs

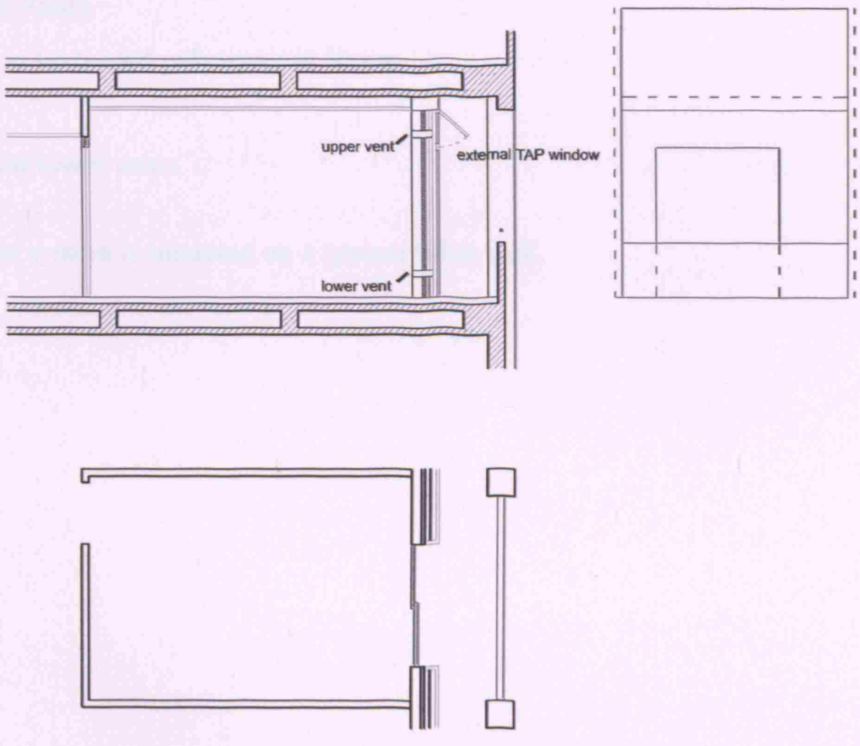


Figure 2.19. Plan, section and elevation of TAP Office

The occupancy pattern of the building (7.30 am-3.30 pm, 5 days/week apart from some offices where there is continuous occupancy) required a system of a medium thermal mass, so that the heat absorbed could be dissipated inwards relatively quickly. The time lag should not be of large range [12]. In addition, the insulation on the external layer of the conventional wall of the TAP is considered as an advantage, as it minimizes heat losses of the system. This attribute is important particularly during not very sunny days and mostly during night time, as a moveable type of insulation would be required alternatively [13].

The parts of the TAP (Figure 2.20) are the following (exterior to interior):

- collector-double glazing
- airspace
- absorber (corrugated iron sheet painted blue)
- airspace 20mm
- insulation (extruded polystyrene) 50mm

- upper and lower vents

The whole system is mounted on a typical brick wall.

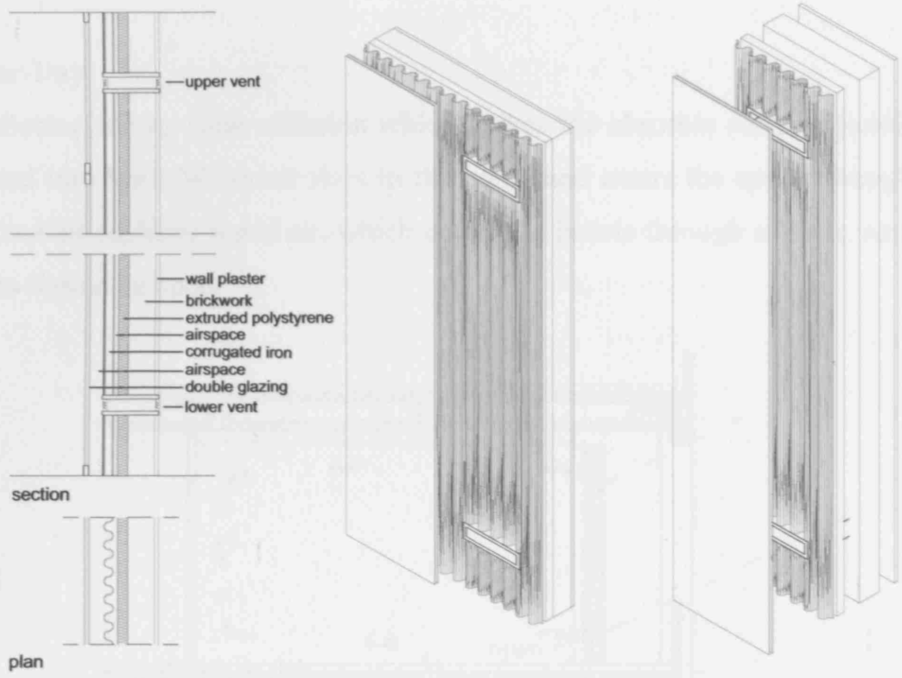


Figure 2.20. TAP detail. Plan, section and 3D views

It is a front pass TAP (discussed in section 2.4.1.2), where the air stream passes in front of the absorber [14]. It must be noted that it is the least efficient configuration, due to the heat losses to the cold glazing, but the construction is simple and less expensive [15].
The basic principle is that hot air rises.

• Environmental Diagrams

▪Winter-Day

The collector admits solar radiation which strikes the absorber surface. Sunlight is thus converted into heat. Warm air rises in the panel and enters the space through an upper vent. Cool air replaces warm air, which enters the panels through a lower vent [16]. The dampers should be open.

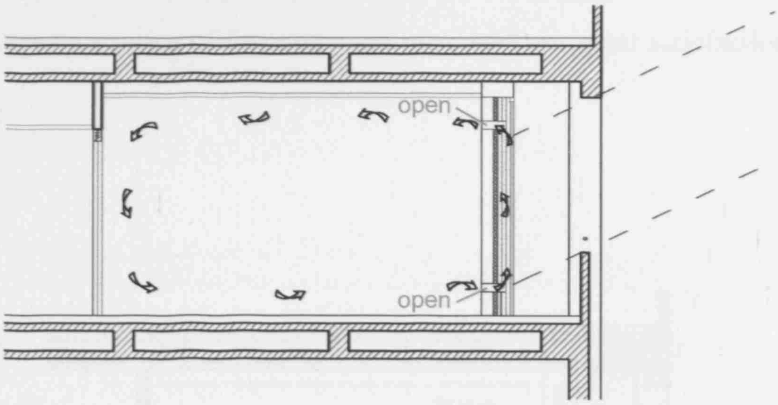


Figure 2.21. Environmental diagram – Winter Day

▪Winter-Night

To prevent any heat from the living space flowing out through the upper vent, or cool air in the panel entering through the lower vent, the dampers of both upper and lower vents should be closed.

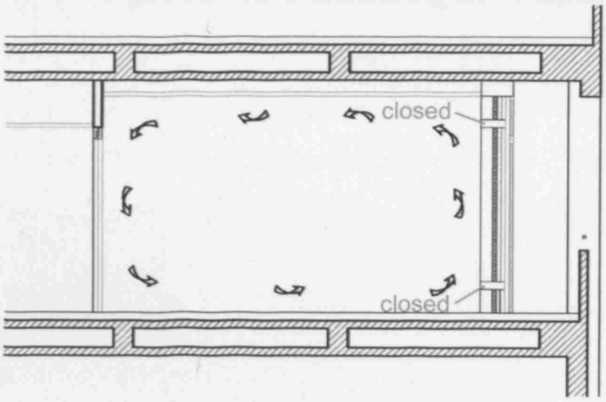


Figure 2.22. Environmental diagram – Winter Night

▪Summer-Day

The passive solar system is set in non-operation by shading from the projection of the volume of the upper floor and by closing the damper of the upper vent in order to prevent warm air from the panel entering the office space. [17]

Leaving the vent over the door level at the opposite wall and the damper of the lower vent, as well as the upper external window of the TAP open, can create an air movement. Warm air in the panel rises and draws cool air through the lower vent from the living space. If the outside air temperature is higher (summer), even an "increased air movement can create a sense of freshness and increased occupant satisfaction" [18].

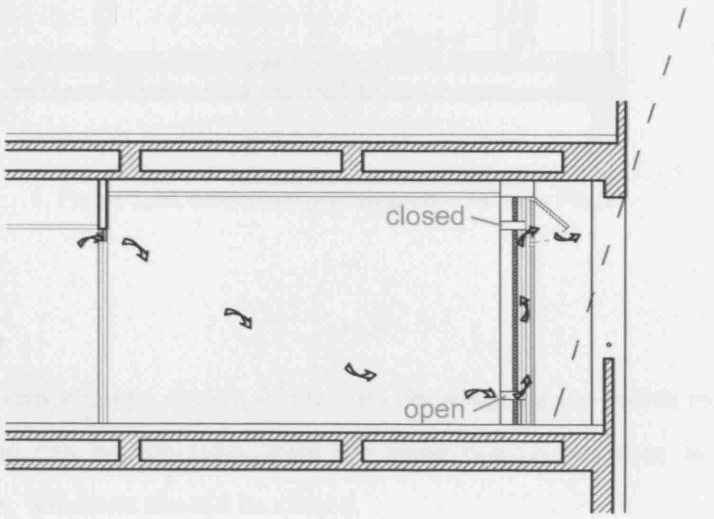


Figure 2.23. Environmental diagram – Summer Day

▪Summer-Night

Since external temperature can be higher than the internal, the dampers of the upper vents should be closed. When windows can be left open (upper levels), the air movement described in "Summer-Day" can remove heat accumulated during the day from the spaces.

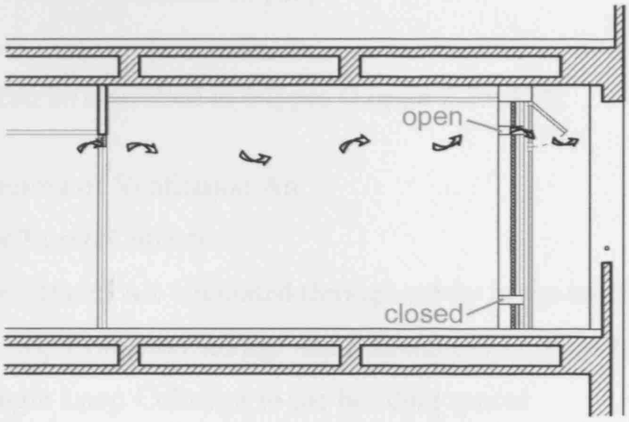


Figure 2.24. Environmental diagram – Summer Night

▪Mid-season-Day

If the external air temperature, drawn in through openings on the North external walls, is lower, free cooling can be achieved, with the same configuration as in the "Summer-Day". If it is lower, windows should be closed.

▪Mid-season- Night

Windows should be closed, as well as the upper and lower dampers. In this way any heat accumulated during the day will be retained in the space for the following morning. In addition, cool air from the panels will not be drawn in the space through the lower vents, inducing warm air escaping through the upper vent.

For the proper operation of the system it is of great importance to ensure that the upper and lower vents are unobstructed. Therefore, the interior furniture and equipment of the offices is laid out leaving these areas unobstructed. [19]

2.4.1.2. Thermosyphon Panels

The Thermosyphon panel system, or Thermosyphon Air Panels (TAPs) as they are frequently referred to [20] is a convective loop system. It is primarily a heating type system and most appropriate for moderate to severe climates [21] and can be considered as particularly suitable for retrofit of existing buildings [22]. The basic principle is that a fluid such as air, will rise when heated [23].

Solar air systems can be classified in 6 types (Figure 2.25) [24]

- Type 1: Solar Heating of Ventilation Air
- Type 2: Collector/Room/Collector
- Type 3: Collector-Heated Air circulated through cavity in the building envelope
- Type 4: Closed Loop Collector/Storage and Radiant discharge to building spaces
- Type 5: Open Single Loop Collector to the building spaces
- Type 6: Collector-Heated Air transferred to water via and Air/Water Heat Exchanger

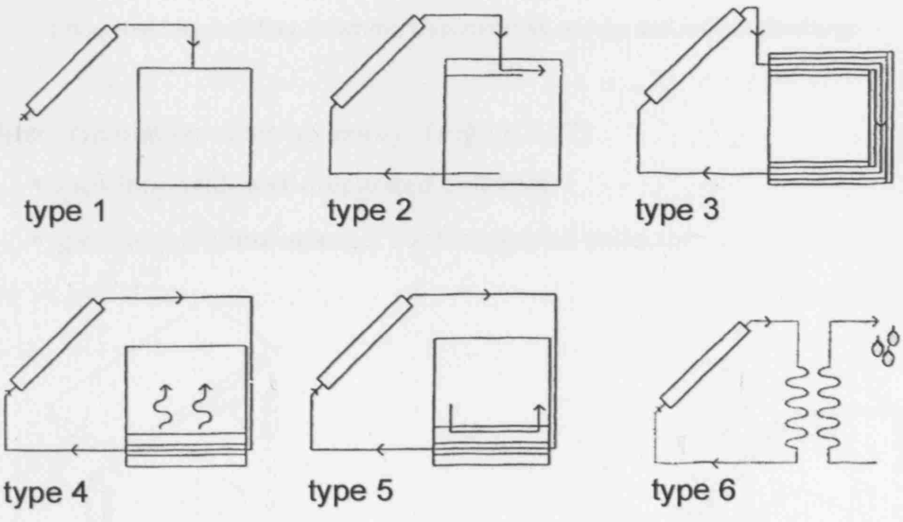


Figure 2.25. Types of Solar Air Systems

The TAP system is a variation of Type 2, an open loop system.

Depending on the way air circulates (directly into a space or through a ceiling void) or if storage is included or not, open loop systems have the following variations: [25]

- Indirect circulation of air-storage (Figure 2.26)
    - thermosyphon collector - radiant discharge storage - room space, integrated into building structure
    - fan driven collector with hypocaust as storage and radiant discharge to space

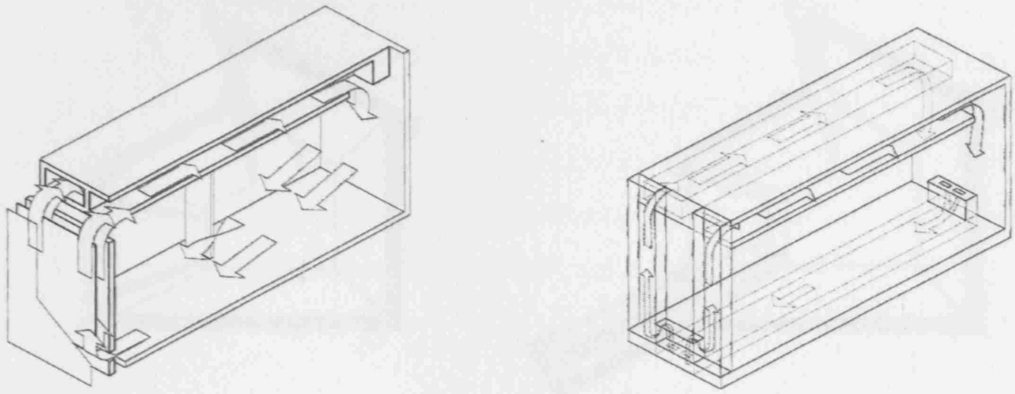


Figure 2.26. Open loop system – Indirect circulation –
Integrated into building structure, Hypocaust as storage and radiant discharge

- Direct circulation of air-no storage (Figure 2.27)
    - open loop with wall-integrated collector
    - open loop without storage: roof integrated collector

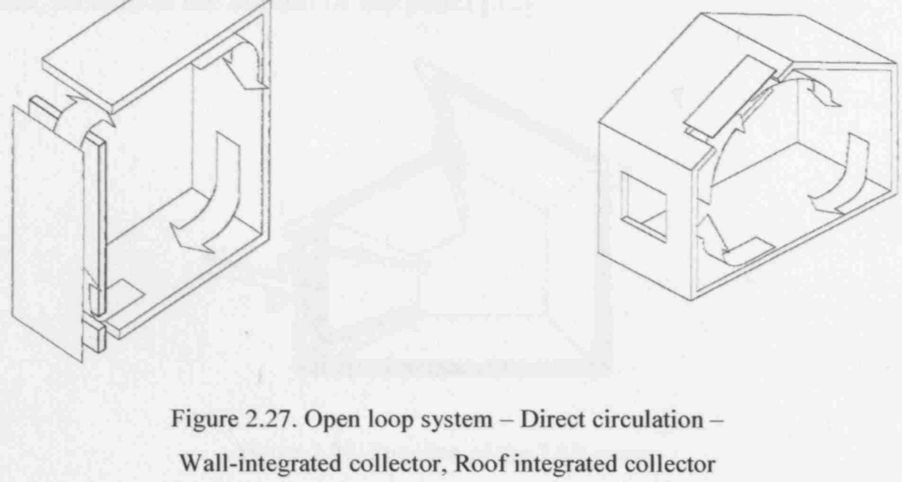


Figure 2.27. Open loop system – Direct circulation –
Wall-integrated collector, Roof integrated collector

A very important element of the convective loop design is the solar collector panel [26]. They are similar, both in appearance and in operation to active solar panel collectors, but the TAP are typically mounted on external south-facing walls in vertical positions (Figure 2.28), while active solar panels are generally roof mounted. They are mounted outside the insulation and thus they thermally isolate the panel from the living spaces [27]. TAP can also be mounted below the floor in an angle (Figure 2.28) [28].

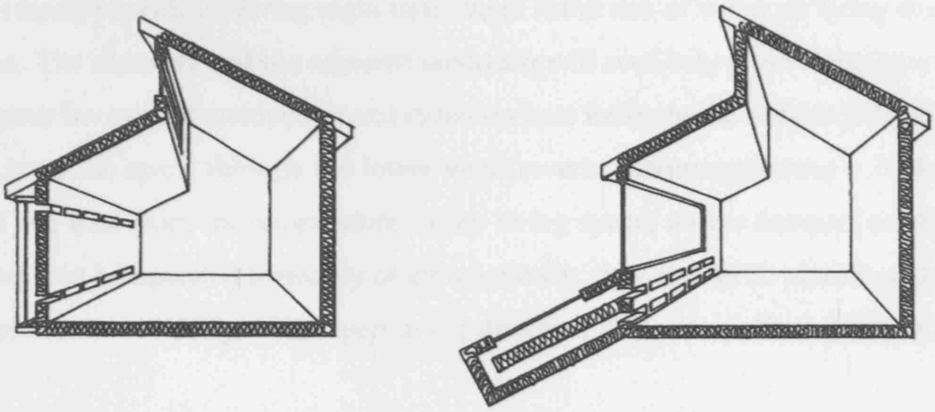


Figure 2.28. Location of TAPs: wall-mounted and below floor in angle

The basic principle, as mentioned, is that hot air rises (Figure 2.29). The collector admits solar radiation, which strikes an absorber surface and is converted to heat [29]. In the convective loop, the heat absorbed is not stored in thermal mass, but is directly transferred to the air surrounding the absorber [30]. The heated air rises inside the TAP, it passes through a vent located at the top and is then distributed directly into the room [31]. As this air circulates through the upper vent, it is replaced by cooler air entering through a lower vent, located at the bottom of the panel [32].

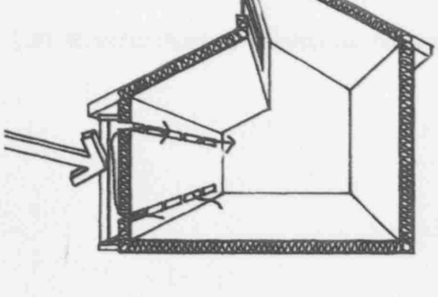


Figure 2.29. Function of the TAP sytem

All the air movement is by natural convection, though there are cases with small fans [33]. Including remote storage, apart from the complexity, would require higher cost and should be considered only when “the system is designed to provide a substantial percentage of the home’s total heating requirements” [34].

During cloudy periods or during night time, there is the risk of warm air being drawn into the room. The absorber and the adjacent airstream will cool below the temperature of the living space because of conduction and radiation heat losses to the outside [35]. This cool air will enter the space through the lower vent (reverse thermosyphoning – Figure 2.30) and will rob heat from the temperature of the living space, unless dampers are provided [36]. They can be operated manually or automatically, they should be placed on the upper and lower vents and designed to open in the direction of warm air-flow, closing at other times.

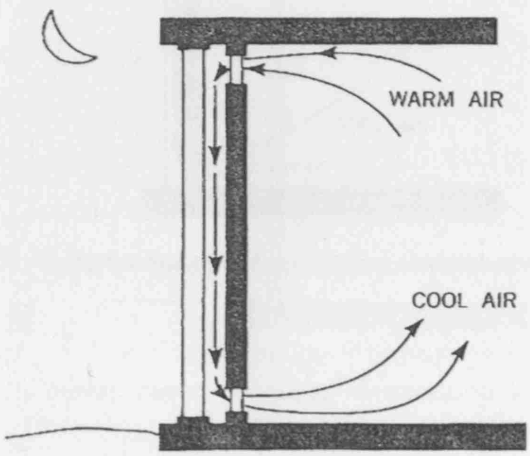


Figure 2.30. Reverse thermsyphoning having a cooling effect

During cooling season, convective loop systems are inactive [37]. The TAP should be completely isolated from the living space, by closing the dampers. Thus, excessive heat will be prevented from the internal space. Additionally, shading or covering the TAP will opaque materials can prevent unwanted heat buildup [38]. If this is not the case, particularly if the TAPs are not vented, very high temperatures can occur and consequently panel seals can be stressed, as well as materials wrap and damage on the absorber surface [39]. However, if dampers are designed correctly, they can be used to induce natural ventilation though buildings, with cool air drawn into the building by the "chimney exhaust system" caused by the solar heated air (Figure 2.31) [40].

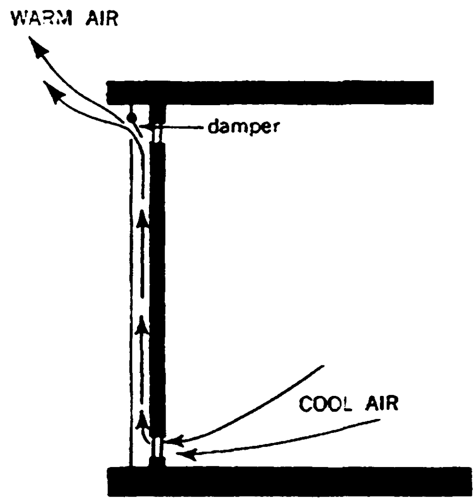


Figure 2.31. Using thermosyphoning to induce convection/ventilation

Absorber

"The absorber material is typically metal, painted black to effectively absorb solar radiation" or instead of paint a selective surface can be specified [41]. The absorber plate is typically corrugated metal decking or expanded lath [42].

There are three configurations for the absorber plate in the vertical panel subsystem (Figure 2.32) [43]

- back pass absorber: Air flows between the absorber plate and the inside wall. Thus, the airflow is separated from the cold collector component by a dead airspace, minimizing in this way heat losses, as the layer of air contained between the absorber and the glazing provides insulation [44]. In addition, the amount of transmitted solar radiation is not reduced by dust and dirt, as they cannot settle on the glazing. For these reasons, this configuration is favoured in many TAP installations.
- front pass design: The airstream passes in front of the absorber plate. Because of the heat losses from the cold glazing, this configuration is the least efficient, despite the simplified construction and reduced cost.
- dual pass design: It allows the airstream to move both in front of and behind the absorber. It is the most effective. As air is a poor conductor of heat, it is beneficial to expose as much of the moving airstream to the absorber plate surface as possible. In this configuration, twice as much surface area is exposed to passing air. However, it is the most expensive and difficult to construct.

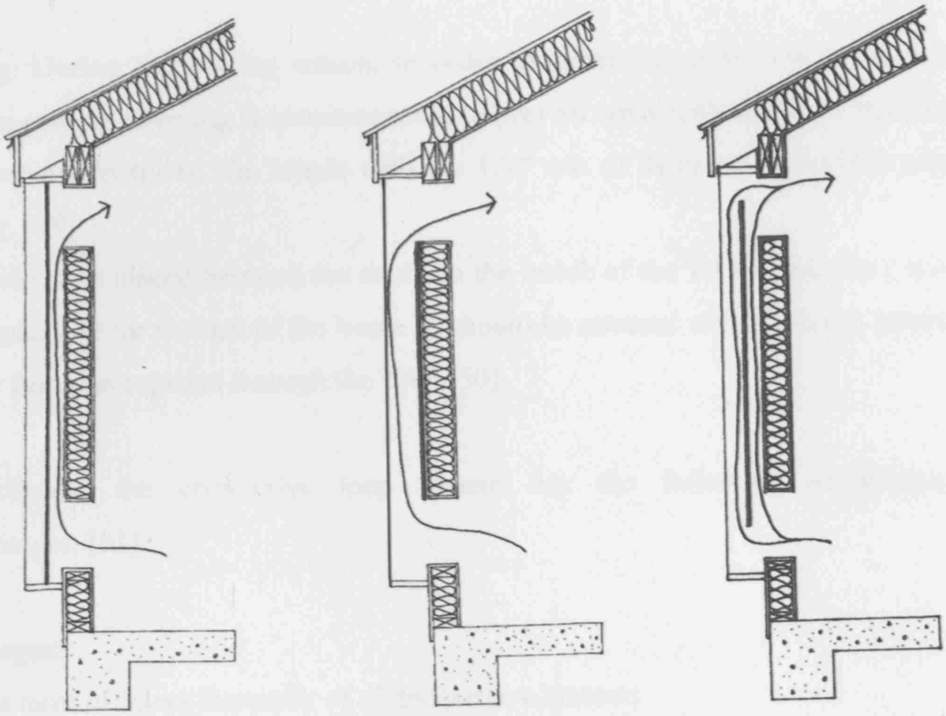


Figure 2.32. Configurations for the absorber plate in the vertical panel subsystem – back-pass, front pass and dual-pass

The area of the absorber should be slightly larger than, and directly behind, collector glazing. The cross sectional area of the flow channel within the collector and of the vent influences air flow rates and thus the collection efficiency [45]. If possible, all the vents should have the same are as that of the channel, even though if this area is reduced by half, only a 10% reduction in total heat benefit from the collector occurs [46]. The maximum cross-sectional area of the channel is about 1/10 of the collector area, as an increase above this limit may decrease the collectors performance by setting up convection currents within this space [47].

As for the flow channel, the depth (D) should be 1/15 the length (L) of the glazing. The airspace (back pass vertical panel), that is the airspace between the absorber and glazing, should be from 5/8"-1 ¾" [48].

Control

- Shading: During the cooling season, in order to avoid excessive heat buildup in the TAP, an opaque covering is recommenced, to prevent solar radiation from reaching the absorber. Alternatively, the façade with the TAP can de designed to provide adequate shading. [49]
- Insulation: It is placed between the studs on the inside of the TAP to the same levels as those specified for the rest of the home. It should be covered with a smooth material so that air flows unimpeded through the TAP [50].

In conclusion, the convective loop system has the following advantages and disadvantages: [51]

Advantages:

- It is the most efficient thermally of all the passive systems
- It is relatively inexpensive and simple to construct (system without storage)
- It is isolated from the living space, allowing for control over heat gains and losses to and from the system
- The TAP (not vertical) can be physically separated from the space, allowing for flexibility in the design

Disadvantages:

- Consideration should be given to the appearance of the panels, as the TAP can be an aesthetic liability
- It has only one function-providing heat-unlike other systems such as the direct gain and attached sunspace, which can provide light and additional living space
- It can obstruct light and view
- Cleaning and maintenance are important issues to ensure good indoor air quality. In addition, dust and smoke film that may gradually form on the inner surface of the cover, can reduce the transmittance of the cover or detract from the appearance of the system [52]

2.4.2. Passive Cooling

The brief required a number of small offices, to correspond to the various departments of the Police Station. This is a significant drawback, in terms of applying a natural ventilation and cooling strategy, as an open plan office design is a common and effective strategy. The problem was overcome by the following measures:

- Sufficient areas of external windows and generally openings are designed. In addition, vents are incorporated in the construction of internal walls, above the door level. In this way, forced movement of air is induced from outside (the North, where the prevailing winds come from) to either certain windows on the opposite side through the internal vents or to the atrium windows and then outside (Figure 2.33, 34)[53]. It is a cross ventilation strategy.

- The glazed covering of the atrium allows solar radiation to penetrate, which is then captured by absorbing surfaces [54]. Heat is released to the air by convection and thus buoyancy is promoted (Figure 2.35) [55]. Fresh, cool air is drawn via windows on the different levels and warm air is exhausted through the openings of the atrium (stack effect). In this way, air can be drawn from both sides of the building, regardless of the prevailing wind [56].

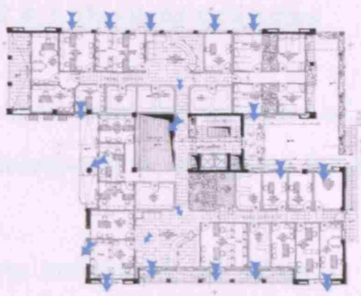
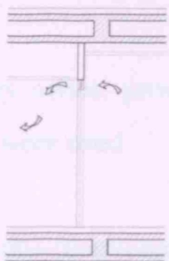
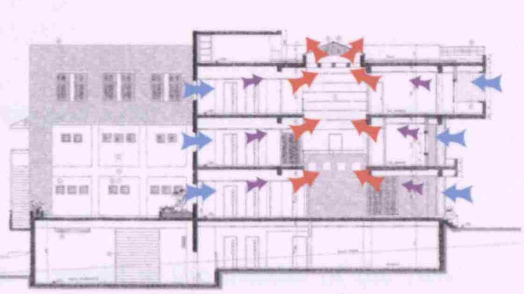




Figure 2.33. Air-flow pattern in the building-plan
Figure 2.34. Integrated vents over door level
Figure 2.35. Air-flow pattern in the building-section

▪ **Clerestory windows** were designed on the roof of the South volume, above the corridor of the second floor (Figure 2.36). They can serve either as a wind trap, allowing for air to penetrate the building, or as a means of exhausting warm air from the interior (Figure 2.37) [57].

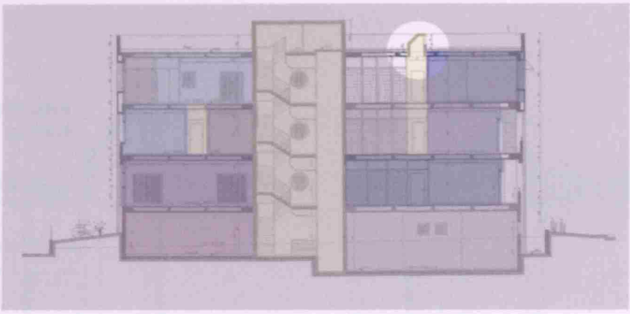


Figure 2.36. Cross-section of building indicating location of clerestory windows

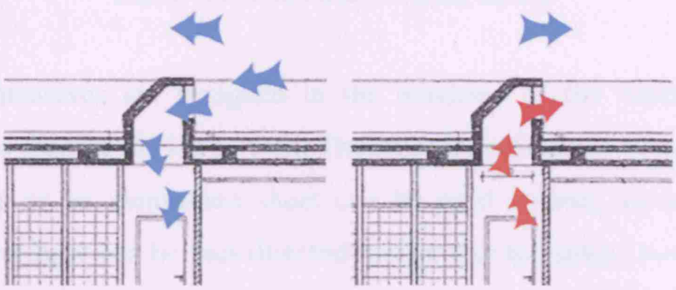


Figure 2.37. Function of the Clerestory windows

2.4.3. Daylight strategies

Apart from the windows of every office, providing natural light, views and ventilation inlets-outlets, additional features were used.

As mentioned, the atrium is a multi-functional space. Located in the middle of the two volumes it provides a "space for circulation and social interaction" [58]. It allows for natural light to penetrate into the centre of the building, thus creating an attractive and usable space, the entrance space, where the basic circulation areas of the upper floors overlook to.

Similarly, the clerestory windows of the second floor, allow natural light into the corridor of the floor, minimizing in this way, the use of artificial lighting. The white, reflective surface of the ceiling [59] directs and diffuses sunlight over the space in an improved way (Figure 2.38). They were designed carefully in order to avoid overheating during summer (discussed in 2.4.4).

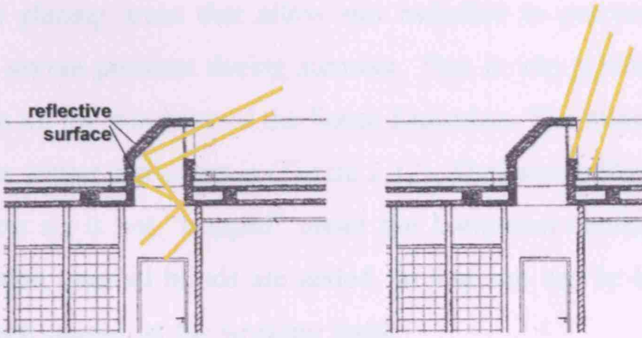


Figure 2.38. Direct solar gain through Clerestory windows,
Rejection of solar radiation during summer

Additionally, lightshelves are designed in the windows of the South Elevation. The feature serves as a shading device as well. Their upper surface can be either painted with aluminium colour or an aluminium sheet can be used instead, so as to increase the reflectance. Natural light can be thus directed further into the space, avoiding at the same time the problem of glare on the working level near the window (Figure 2.39) [60].

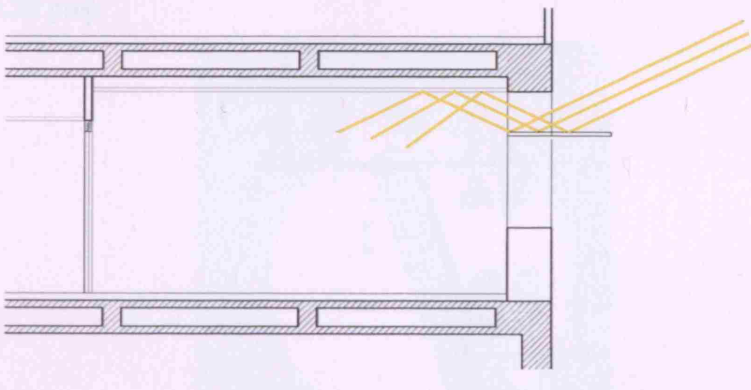


Figure 2.39. Function of Lightshelves

2.4.4. Shading-Control of Overheating

The strategies described for passive heating, cooling and daylight are designed so as to control the risk of overheating. The features are designed carefully and there is operation for winter and summer mode or additional features.

Sufficient south glazing areas that allow sun radiation to penetrate the spaces during winter can be a severe problem during summer. That is why horizontal shading devices were designed in all the windows of the South Elevation. The dimensions are defined by the solar angle in winter and summer (Figure 2.17). They are perforated metal overhangs. In this way warm air is not "trapped" under the horizontal overhang [61]. In addition, horizontal Venetian internal blinds are added, so that sun can be blocked during winter when problems are caused on the working level.

Apart from the windows, most of the walls with the TAP are shaded during the summer period as well by the balconies, which are constructed for that particular reason. They work as overhangs. Their width is defined in order to block sun penetration during summer (Figure 2.17).

On the west part of the building there is solar shading for the second floor offices. A series of fixed concrete vertical louvres are designed, as vertical elements are required for west orientation (Figure 2.30). The louvres are designed in a detailed way. They are tilted taking into account the sun angle in the worst case scenario (summer) and ensuring that sun is blocked until 3.00 pm, approximately after when the building is not occupied [62] (7.30 am – 3.30 pm).

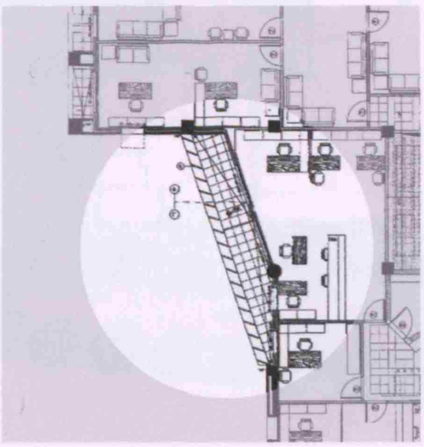


Figure 2.40. West elevation shading- Vertical louvres-plan

The height of the clerestory windows over the corridor of the second floor, is designed so that it allows solar radiation to enter the space during winter, but blocks it during summer (Figure 2.38).

2.4.5. Microclimate

Apart from the features of the building, the outdoor spaces of the whole site and generally the landscape was included in the whole design process, as improving the microclimate conditions can improve the buildings energy performance. Thus, vegetation is designed in a way that good solar access is not inhibited and wind control can be achieved. Trees are planted in the whole perimeter of the site. Evergreen trees are located in the North edge so that the effect of the predominant North winds during winter can be alleviated (Figure 2.41)[63]. Deciduous trees are located in the rest of the perimeter [64]. In this way, sun penetration is not blocked during winter while in summer a means of shading the external envelope of the building is provided. In addition, a water feature is designed to enhance evaporative cooling during summer [65]. Water flows around the building and forms small ponds in certain parts.

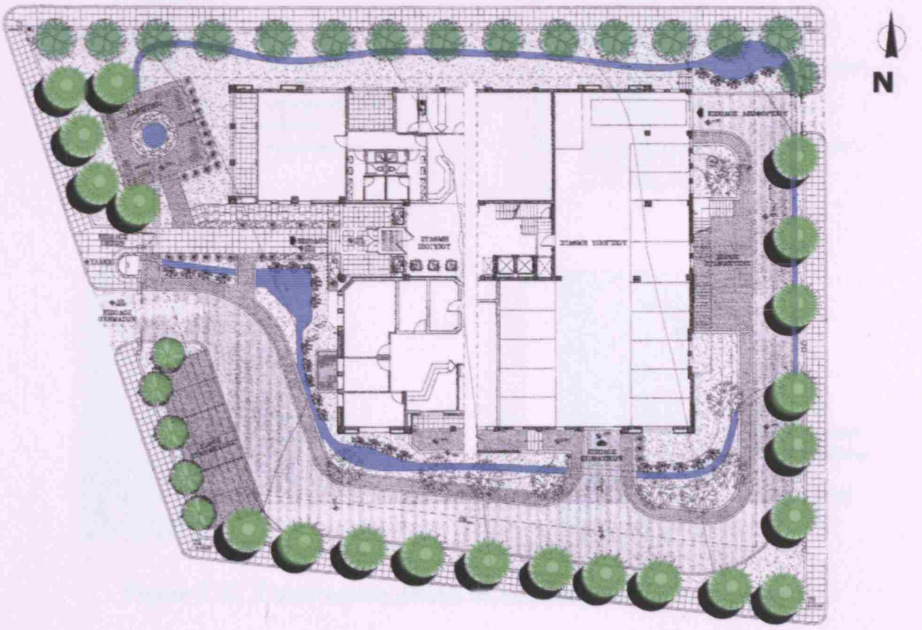


Figure 2.41. Plan of outdoor spaces – Evergreen and Deciduous trees – Water feature

2.5. MATERIALS

The building's structure is of reinforced concrete. The external walls are brick walls, with an additional layer of external cement blocks at some parts. The internal walls are either brick walls or gypsum plaster lath construction.

In order to minimize fabric heat losses

- Insulation was included in the construction of all the external elements (walls or structural elements) with extruded polystyrene. The width was determined by the insulation design of the building and its thermal performance using the SUNCODE software [66]
- Double glazing windows were designed – total width 25mm (6+12+5). [67]

Floors are covered with marble or ceramic tiles. There is a timber overlay in the gym.

There is false ceiling to provide space for the services.

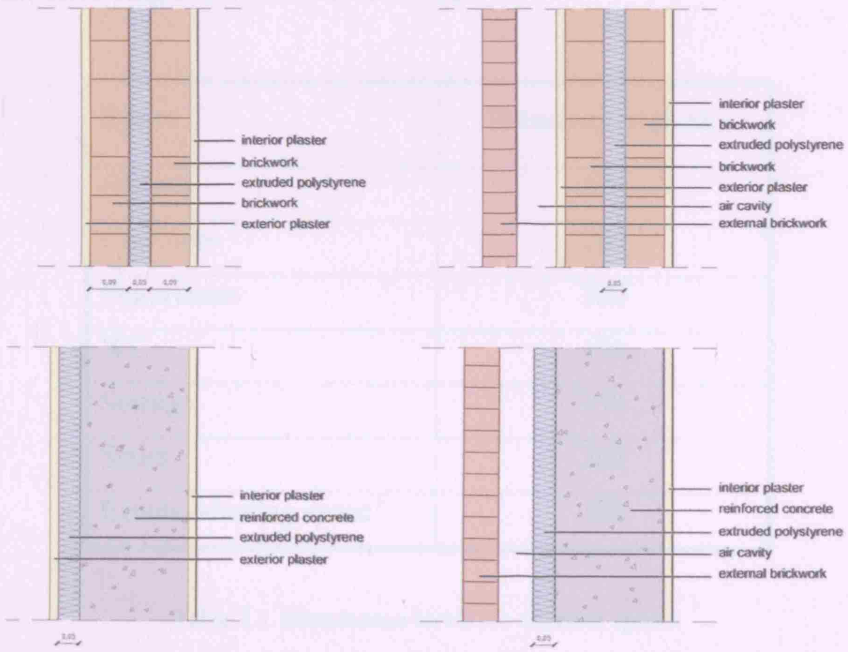


Figure 2.42. Construction details of external structural elements

2.6. SERVICES SYSTEMS

Heating/Cooling: There is a central heating system with two oil-fired boilers - 85% efficiency (Basement Plant Room), while cooling demands are provided by two cooling towers, located on the roof [68]. There are Perimeter Fan Coil Units (FCU) in all the office areas. Mechanical Ventilation is installed to be used when required, by three Air Handling Units (AHU), one for each floor, located on the roof as well. The FCU are controlled by the occupants. Domestic Hot Water (DHW) is provided by electrical water heaters [69].

There is a separate Variable Refrigerant Flow system (VRV) serving the events-meeting space, the shooting space, the gym and the Chief's flat [70].

2.7. ARTIFICIAL LIGHTING

The artificial lighting was designed according to the requirements by DIN 5035 [71] providing the following Illuminance levels [72]:

Space	**Illuminance (Lux)**
Offices	300
Corridors	200
Plantrooms	200
WC	150
Storage	150
Stairs	200
Events-Meeting space	300

Table 2.1. Illuminance levels for different spaces

In the offices areas, stairs and corridors, the lighting is fluorescent with recessed luminaires (600 x 600 mm) for linear fluorescent lamps (4 x 18 W) without controls [73]. Recessed circular luminaires for compact fluorescent lamps (2 x 18 W) with dimmers are used in the events-meeting space [74]. Incadescent lamps (60 W) are used in the facilities and cell areas [75].

Apart from the interior of the building, lighting of the external spaces is required as well. This includes the building elevations, the entrances to the building and the basement parking space, the roof and the outdoor spaces.

2.8. DISCUSSION

The whole design of the scheme is done in a holistic approach. Zoning of spaces with similar heating/cooling requirements was applied, taking into consideration the Departments Division.

The choice of the Passive Solar Systems (direct gains and TAP) was a justified solution, in terms of capital and operation cost and simplicity in construction. Taking into account the occupancy pattern of the building, the TAP system was very suitable, as the heat generated should be transferred into the occupied areas without a great time lag. In the design of Passive Solar Systems, there was provision for shading in order to avoid overheating without compromising the buildings performance in terms of natural lighting.

In the same way, other features such as the atrium and the clerestory windows were designed not only for architectural and natural lighting purposes, but for cooling and passive solar heating as well, again with provision for shading, when possible (clerestory windows).

High quality insulation materials were chosen and double glazing was applied in order to reduce heat losses.

It is important that environmental strategies were not applied only in the building, but in the surrounding areas as well, as an attempt to improve the microclimate conditions.

However, there are some issues that need to be discussed. The natural cooling by opening windows and exhaustion of warm air from the atrium might function properly in mid-season conditions of the particular climate. Despite the fact that it is a simple and economic solution, it might not be effective in typical summer conditions, when external air temperature during the occupancy schedule is high (>25^{0}C).

Similarly, the TAP system may have good performance during winter, but it is not certain if it can provide adequate cooling in typical summer conditions. In addition, while the TAP offices adjacent to the balconies were completely shaded during summer, there was no provision for shading in the rest of the TAPs mounted directly on external South walls. This might cause overheating problems during summer.

The choice of an exposed ceiling slab, instead of the false ceiling, might improve the internal conditions, providing a heat sink for internal gains.

For DHW purposes, the electrical water heaters could have been avoided, by installing solar water heaters instead.

Finally, it should be noted that the buildings layout allows for adequate solar radiation during winter. However, in a worst case scenario, if a new construction is built in the adjacent south site with the maximum height permitted (15m), the Ground Floor South external wall will be shaded during winter (Figure 2.43). Thus, the TAP installed will not function. This might suggest that theses Passive Solar Systems should be installed on the 1st and 2nd floor.

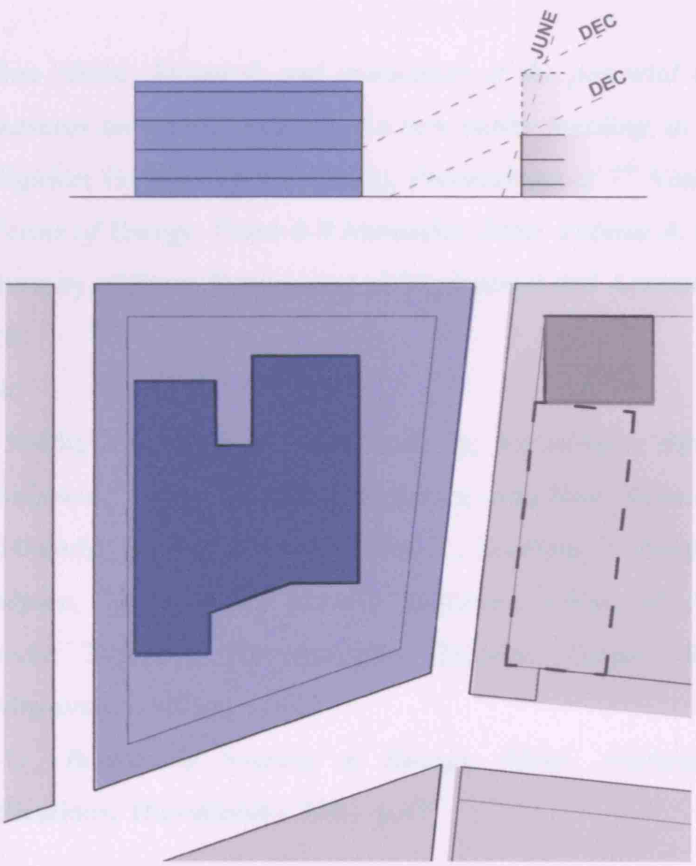


Figure 2.43. Site plan and Section indicating effect of future worst-case scenario concerning adjacent building

Overall, despite of the points discussed above, the environmental design of this Public building is quite interesting, taking into consideration the vague requirements of the brief. The performance of the different systems will be evaluated using computer simulation (TAS) and the results will be discussed in Chapter 5.

REFERENCES

[1] Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.328

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

[2] Tsiligiridis G., *Renewable Sources of Energy, Notes*, Aristotle University of Thessaloniki Publications, Thessaloniki, 2001, p.47

[3] as [2], p.47

[4] as [2], p.47

[5] Site Plan of "Police Station of Kilkis", Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

[6] Hellenic Public Real Estate Corporation, *Competition Brief: Design and Construction of Police Station in Kilkis, 1. Public Proclamation of Open Competition*, Hellenic Public Real Estate Corporation, Athens, 1999, p.3-4

(original in Greek:

Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Τεύχη Δημοπράτησης, 1. Διακήρυξη Ανοιχτής Δημοπρασίας*, Κτηματική Εταιρία του Δημοσίου, Αθήνα, 1999)

[7] Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar

Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.326

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

[8] as [7], p.326

[9] as [7], p.327

[10] as [7], p.328,329

[11] as [7], p.327-328

[12] as [7], p.328

[13] as [7], p.328

[14] Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 207

[15] as [14], p.207

[16] as [14], p.201, 203

[17] Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.328

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002,* Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

[18] CIBSE, Applications Manual AM10: 1997, Natural Ventilation in Non-Domestic Buildings, The Chartered Institution of Building Services Engineers, London, 1997, p. 13

[19] Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.328
(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

[20] Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 201

[21] as [20], p.16

[22] Achard P., Gicquel R. (editors), *European passive solar handbook : basic principles and concepts for passive solar architecture*, Preliminary edition, Commission of the European Communities, Directorate General XII for Science, Research and Development, Brussels, 1986, p.4-32

[23] Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 16

[24] Hastings R., Mærck O. (editors), *Solar Air Systems: a Design Handbook*, James & James, London, 2000, p.5

[25] as [24]. p.38

[26] Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 201

[27] as [26], p.203

[28] as [26], p.201

[29] as [26], p.201

[30] as [26], p.201

[31] as [26], p.201

[32] as [26], p.201

[33] as [26], p.201

[34] as [26], p.203,204

[35] Anderson B., *Solar Energy: Fundamentals in Building Design*, McGraw-Hill, New York, 1977, p.96

[36] Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 208

[37] as [36], p.204

[38] as [36], p.204

[39] as [36], p.204,205

[40] Anderson B., *Solar Energy: Fundamentals in Building Design*, McGraw-Hill, New York, 1977, p.96,97

[41] Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 206

[42] as [41], p.206

[43] as [41], p.206-208

[44] Department For Education, Architects and Building Division, Building Bulletin 79: *Passive Solar Schools: A design guide*, HMSO, London, 1994, p.31

[45] Lebens R., *Passive Solar Heating Design*, Applied Science Publishers, London, 1981, p.19

[46] as [45], p.19

[47] as [45], p.19

[48] Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 209

[49] as [49], p.211

[50] as [49], p.211

[51] as [49], p.205

[52] Department For Education, Architects and Building Division, Building Bulletin 79: *Passive Solar Schools: A design guide*, HMSO, London, 1994, p.31

[53] Crysomallidou Niobe, *Research of the efficiency of specific strategies for the improvement of natural cooling and lighting of office buildings*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.319

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση της Αποδοτικότητας Συγκεκριμένων Προτάσεων για τη Βελτίωση του Φυσικού Δροσισμού και Φωτισμού Κτιρίων Γραφείων*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

[54] CIBSE, *Applications Manual AM10: 1997, Natural Ventilation in Non-Domestic Buildings*, The Chartered Institution of Building Services Engineers, London, 1997, p. 29

[55] as [54], p.29

[56] Crysomallidou Niobe, *Research of the efficiency of specific strategies for the improvement of natural cooling and lighting of office buildings*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.319

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση της Αποδοτικότητας Συγκεκριμένων Προτάσεων για τη Βελτίωση του Φυσικού Δροσισμού και Φωτισμού Κτιρίων Γραφείων*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο

Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

[57] as [56], p.319

[58] CIBSE, *Applications Manual AM10: 1997, Natural Ventilation in Non-Domestic Buildings*, The Chartered Institution of Building Services Engineers, London, 1997, p. 29

[59] Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.329

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

[60] Crysomallidou Niobe, *Research of the efficiency of specific strategies for the improvement of natural cooling and lighting of office buildings*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.322

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση της Αποδοτικότητας Συγκεκριμένων Προτάσεων για τη Βελτίωση του Φυσικού Δροσισμού και Φωτισμού Κτιρίων Γραφείων*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

[61] as [60], p.319

[62] as [60], p.319

[63] as [60], p.320

[64] as [60], p.320

[65] as [60], p.320

[66] Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.327
(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002

[67] as [66], p.327

[68] Hellenic Public Real Estate Corporation, *Design and Construction of Police Station in Kilkis, Design Report of Electrical/Mechanical Services-Technical Description* , Hellenic Public Real Estate Corporation, Thessaloniki, 2000, p.8,9
(original in Greek:
Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Μελέτη Εφαρμογής Η/Μ Εγκαταστάσεων, Τεχνική Περιγραφή*, Κτηματική Εταιρία του Δημοσίου, Θεσσαλονίκη, 2000)

[69] as [68], p.8

[70] Hellenic Public Real Estate Corporation, *Design and Construction of Police Station in Kilkis, Design Report of Electrical/Mechanical Services-Technical Design* , Hellenic Public Real Estate Corporation, Thessaloniki, 2000, p.29
(original in Greek:

Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Μελέτη Εφαρμογής Η/Μ Εγκαταστάσεων, Τεχνική Μελέτη*, Κτηματική Εταιρία του Δημοσίου, Θεσσαλονίκη, 2000)

[71] as [70], p.29

[72] as [70], p.29

[73] Hellenic Public Real Estate Corporation, *Design and Construction of Police Station in Kilkis, Design Report of Electrical/Mechanical Services-Technical Specifications* , Hellenic Public Real Estate Corporation, Thessaloniki, 2000, p.66, 67

(original in Greek:

Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Μελέτη Εφαρμογής Η/Μ Εγκαταστάσεων, Τεχνικές Προδιαγραφές*, Κτηματική Εταιρία του Δημοσίου, Θεσσαλονίκη, 2000)

[74] as [73], p.66,67

[75], as [73], p.66,67

SOURCES OF ILLUSTRATIONS

FIGURES

Figure 2.1. http://www.lonelyplanet.com/worldguide/destinations/europe/greece [August 2005]

Figure 2.2. http://www.expedia.com/pub/agent.dll?qscr=over&rfrr=-357 [August 2005]

Figure 2.3. based on Tsiligiridis G., *Renewable Sources of Energy, Notes*, Aristotle University of Thessaloniki Publications, Thessaloniki, 2001, p.47, Table 3.8

Figure 2.4. as Figure 2.3, p.48, Table 3.9

Figure 2.5. as Figure 2.3, p.50, Table 3.13

Figure 2.6. as Figure 2.3, p.50, Table 3.14

Figure 2.7. Goulding J., Lewis O., Steemers T. (editors), *Energy Conscious Design-A Primer for Architects,* European Commission- Directorate General XII for Science, Research and Development, London, 1992, p.31

(original in Greek:

Goulding J., Lewis O., Steemers T. (επιμ.), Ενεργειακός Σχεδιασμός. Εισαγωγή για Αρχιτέκτονες, Μαλλιάρης, Θεσσαλονίκη, 1994)

Figure 2.8. based on Tsiligiridis G., *Renewable Sources of Energy, Notes*, Aristotle University of Thessaloniki Publications, Thessaloniki, 2001, p.44, Table 3.2

Figure 2.9. Goulding J., Lewis O., Steemers T. (editors), *Energy Conscious Design-A Primer for Architects,* European Commission- Directorate General XII for Science, Research and Development, London, 1992, p.23

(original in Greek:

Goulding J., Lewis O., Steemers T. (επιμ.), Ενεργειακός Σχεδιασμός. Εισαγωγή για Αρχιτέκτονες, Μαλλιάρης, Θεσσαλονίκη, 1994)

Figure 2.10. based on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

Figure 2.11. as Figure 2.10

Figure 2.12 as Figure 2.10

Figure 2.13. as Figure 2.10

Figure 2.14. as Figure 2.10

Figure 2.15. as Figure 2.10

Figure 2.16. as Figure 2.10

Figure 2.17. based on Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.329 Figure 4,
(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7^{ου} Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)
and on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

Figure 2.18. based on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

Figure 2.19. based on Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.328 Figure 3,
(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά*

7^ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αερονaυπηγών Μηχανικών, Πάτρα, 2002)
and on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

Figure 2.20. as Figure 2.19

Figure 2.21. as Figure 2.19, p.328 Figure 3

Figure 2.23. as Figure 2.21, p.328 Figure 3

Figure 2.25. Hastings R., Mærck O., (editors), *Solar Air Systems: a Design Handbook*, James & James, London, 2000, p.5, 6, Figures I.1.1.-I.1.6.

Figure 2.26. as Figure 2.25, p.38 Figures II.2.1,2,

Figure 2.27. as Figure 2.25, p.39, Figures II.2.3,4

Figure 2.28. Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 202, Figures 6.1,2

Figure 2.29. as Figure 2.28, p. 202, Figure 6.3

Figure 2.30. Anderson B., *Solar Energy: Fundamentals in Building Design*, McGraw-Hill, New York, 1977, p.96, Figure III.A.12.

Figure 2.31. as figure 2.30, p.96, Figure III.A.18.

Figure 2.32. Steven Winter Associates, edited by Crosbie M. J., *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998, p. 207, Figures 6.10,11,12

Figure 2.33. based on Crysomallidou Niobe, *Research of the efficiency of specific strategies for the improvement of natural cooling and lighting of office buildings*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7^th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.319 Figure 1
(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση της Αποδοτικότητας Συγκεκριμένων Προτάσεων για τη Βελτίωση του Φυσικού Δροσισμού και Φωτισμού Κτιρίων Γραφείων*, Ινστιτούτο

Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)
and on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning
Figure 2.34. as Figure 2.33, p.319, Figure 2
and on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning
Figure 2.35. as Figure 2.34, p.319 Figure 3
and on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning
Figure 2.36. based on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning
Figure 2.37. based on, Crysomallidou Niobe, *Research of the efficiency of specific strategies for the improvement of natural cooling and lighting of office buildings*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.319 Figures 4a, b
(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση της Αποδοτικότητας Συγκεκριμένων Προτάσεων για τη Βελτίωση του Φυσικού Δροσισμού και Φωτισμού Κτιρίων Γραφείων*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)
and on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning
Figure 2.38. based on Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in

Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.329, Figure 5

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

Figure 2.39. based on, Crysomallidou Niobe, *Research of the efficiency of specific strategies for the improvement of natural cooling and lighting of office buildings*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.322, Figure10

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση της Αποδοτικότητας Συγκεκριμένων Προτάσεων για τη Βελτίωση του Φυσικού Δροσισμού και Φωτισμού Κτιρίων Γραφείων*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

Figure 2.40. based on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

Figure 2.41. based on, Crysomallidou Niobe, *Research of the efficiency of specific strategies for the improvement of natural cooling and lighting of office buildings*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002,*

Volume A, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.321 Figure 8

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση της Αποδοτικότητας Συγκεκριμένων Προτάσεων για τη Βελτίωση του Φυσικού Δροσισμού και Φωτισμού Κτιρίων Γραφείων*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

Figure 2.42. based on, Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.327 Figure 2

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

Figure 2.43. based on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

TABLES

Table 2.1. based on Hellenic Public Real Estate Corporation, *Design and Construction of Police Station in Kilkis, Design Report of Electrical/Mechanical Services-Technical Design* , Hellenic Public Real Estate Corporation, Thessaloniki, 2000, p.29
(original in Greek:
Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Μελέτη Εφαρμογής Η/Μ Εγκαταστάσεων, Τεχνική Μελέτη*, Κτηματική Εταιρία του Δημοσίου, Θεσσαλονίκη, 2000)

3. CONSTRUCTED BUILDING

3.1. VIEWS OF THE BUILDING

The building was occupied as mentioned in December 2001. The main features can be seen in the following pictures:

Picture 3.1. View of the building from South-West

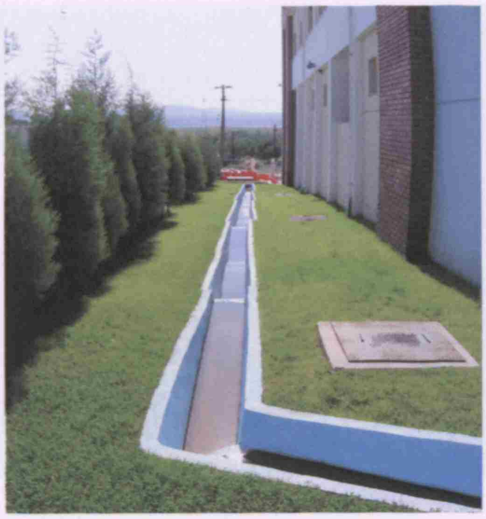
Picture 3.2. Clerestory windows from the roof

Picture 3.3. South Elevation

Picture 3.4.Detail of South Elevation

Picture 3.5. TAPs Elevation

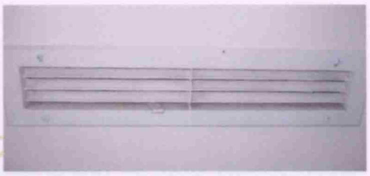
Pictures 3.6, 3.7, 3.8. Details of shading features of South Elevation



Picture 3.9. 3.10, The water feature of the outdoor space

Picture 3.11. TAPs from GF balcony

Picture 3.12. External TAP window



Picture 3.13. View of a 1st Floor TAP Office-space, location of upper and lower vent

Picture 3.14. Vent from interior

Picture 3.15. Vent from exterior

Picture 3.16. View of a GF TAP Office, where vents are blocked by furniture layout

3.2. DIFFERENCES

There are differences between the initial design and the constructed building. Some features were not constructed at all, while other were not constructed as they should have been. The extent to which this affects the energy performance of the building will be investigated in Chapter 5.

- Thermosyphon Panels (TAP): In the initial design, almost all the area of the South facing external walls of the Ground and 1st Floor is covered with TAP. In the existing building, the Passive Solar Heating systems were installed only in the offices adjacent to the balconies (Figure 3.1). In addition, there were differences in the furniture layout in the interior of these offices, affecting the air flow of the system (Picture 3.16), which is discussed in Chapter 4.2.

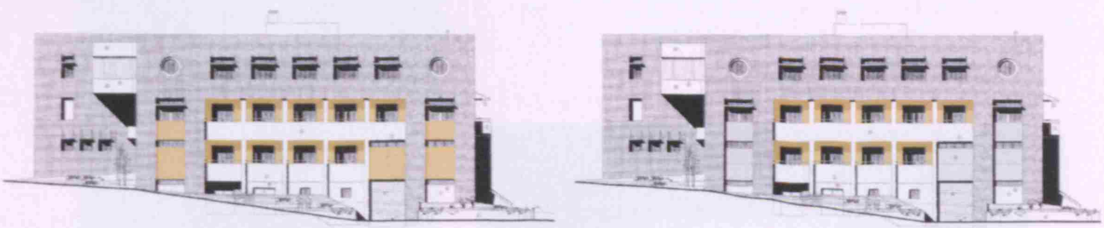


Figure 3.1. South Elevations indicating TAPs in initial design and in constructed building

- Vents in internal walls for passive cooling purposes: The vents that in the initial design were incorporated in the internal walls to allow for air flow in the office spaces were not constructed at all.

- Atrium: It was constructed without opening parts – windows (Picture 3.17, 18).

Pictures 3.17, 3.18. The atrium from the roof and from the interior

▪ <u>Clerestory windows</u>: The ceiling of the corridor below the clerestory windows was covered, incorporating diffuse glass.

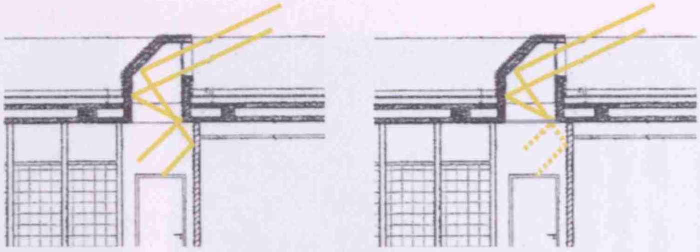
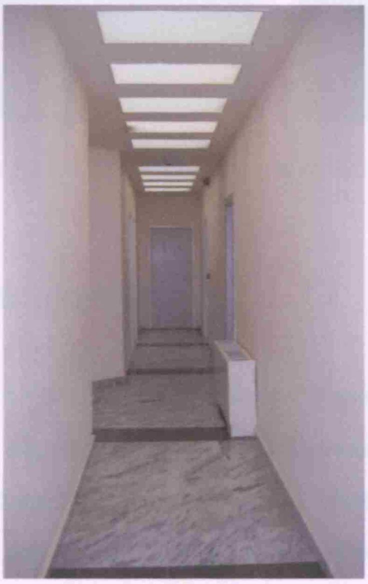


Figure 3.2. Clerestory windows – Initial design and constructed bulding



Pictures 3.19, 3.20. False ceiling below clerestory windows- diffuse natural light - Detail

▪ <u>Lightshelves</u>: Not constructed.

▪ Vertical louvres of the West Elevation: They are not constructed as fixed, concrete louvres. Aluminium sheet was used instead and they are operated from the interior of the office by the occupants.


Pictures 3.21, 3.22. Vertical louvres of the West Elevation – Views from the interior

3.3. DICUSSION

The TAP walls that were not constructed do not correspond to a significant area of the South elevation. What is important to note is that those constructed, are completely shaded during summer, as they should be, to prevent overheating. If the rest of the TAPs, which are located on the external walls without provision for shading, were constructed according to the initial design, problems of overheating might occur during summer.

The area of windows of the South Elevation and the depth of offices on that part of the building are not problematic so as to consider the absence of lightshelves as critical.

The vertical louvres, despite the fact that they are not fixed, can provide shading under proper control by the occupants.

The differences in the features of the atrium, the clerestory windows and the internal walls vents are the most important because they affect the initial ventilation and cooling strategies. By blocking the roof openings (atrium and clerestory windows), warm air cannot be exhausted through the upper parts of the building. Although the contribution to natural lighting is significant, the natural ventilation and cooling strategies are affected to a great extent, relying only on cross ventilation. As for the absence of vents on internal walls, air flow between office spaces can be achieved by having internal doors open. This could be applied not only for passive cooling, but for passive heating as well, as heat generated in the TAP offices could be transferred in offices without Passive Solar Systems. However, this air flow pattern through open internal doors could have a negative effect on the performance and output of the TAP in the office areas where they are located.

The effect of these differences on the energy performance of the building will be investigated using computer simulation (TAS) and discussed in Chapter 5.

SOURCES OF ILLUSTRATIONS

Figure 3.1. based on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

Figure 3.2. based on, Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.329 Figure 5
(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)
and on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

4. OPERATION OF CONSTRUCTED BUILDING

4.1. METHODOLOGY OF INVESTIGATING OPERATION

The building was surveyed and monitored using Hobo data loggers during the period 17.05.05-10.06.05. Temperature and Relative Humidity were monitored both in internal and external conditions. The occupants behaviour was surveyed as well as their evaluation of the environmental conditions in the building, with a questionnaire survey on a typical week-day. Finally, some data on energy consumption were provided. Overall, the investigation of the operation of the building consists of the following:

- Occupants behaviour
- Internal conditions monitoring
- Questionnaire survey
- Energy consumption

4.2. OCCUPANTS BEHAVIOUR

Some comments can be made on the occupants behaviour, related to its effect on the energy performance of the building. Since there are no automatic controls in the services systems, good operation relies on the occupants.

During the monitoring period, it is characteristic that lights were left on during the day in some corridors and common spaces, where there was sufficient natural light.

A significant impact of the occupants behaviour is the one on the TAP system. It is very important for the proper operation of the system that the upper and lower vents of the TAP offices are unobstructed. In most of the offices the furniture layout was not made according to the initial design, blocking the vents and affecting the air flow pattern (Picture 3.16). The upper vents were not closed, as they should have been, as it was end of mid-season-beginning of summer. As for the external TAP windows (Picture 3.11), others were open and others closed. Generally, it was obvious that the majority of occupants were not given any instructions about operating the TAP system, something that was confirmed in the questionnaire survey, discussed in Chapter 4.4.

In some offices, where there was provision for upper opening parts in windows, these were blocked by internal Venetian blinds.

Finally, despite the construction of the water element in the outdoor space, there was no water flowing around the building, as it was designed.

4.3. INTERNAL CONDITIONS MONITORING

The internal and external Temperature and Relative Humidity (17.05.05-10.06.05) were monitored during a period between the end of mid-season and the beginning of summer. There was no air-conditioning during this period and windows were open according to the occupants control.

Three Hobo data loggers were used to monitor the internal conditions in different parts of the building and another one was monitoring the external conditions during the same period. The building was divided in zones according to the spaces orientation (Table 4.1). The zones and the locations of the Hobo data loggers are shown in the following figures:

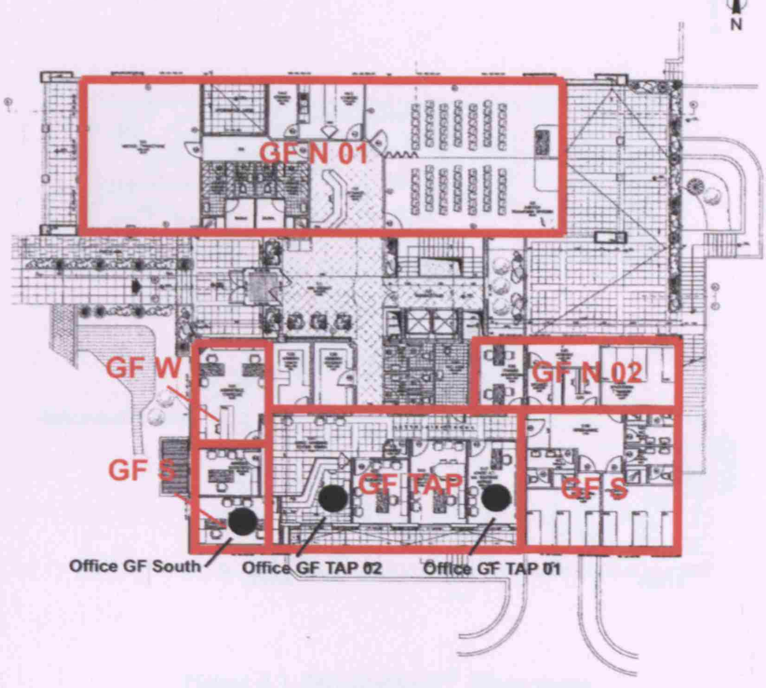


Figure 4.1. Monitoring-GF zones

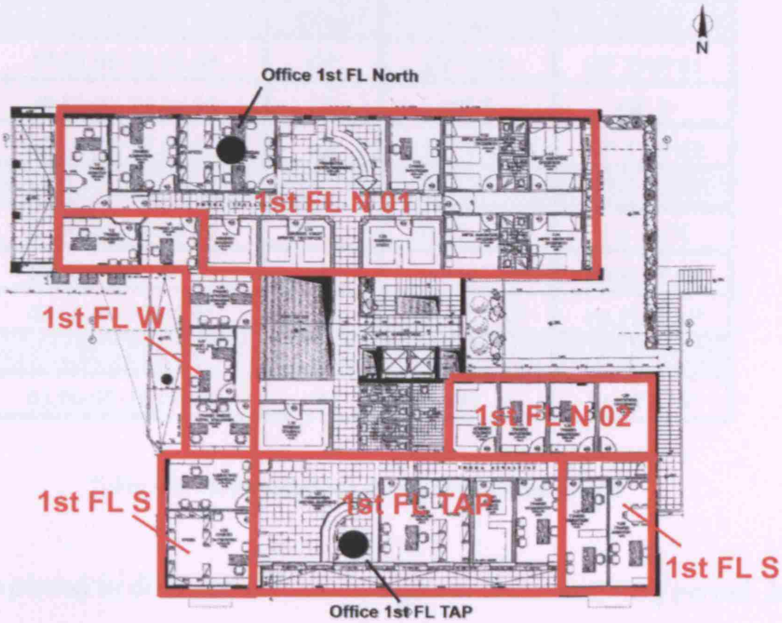


Figure 4.2. Monitoring-1st Floor zones

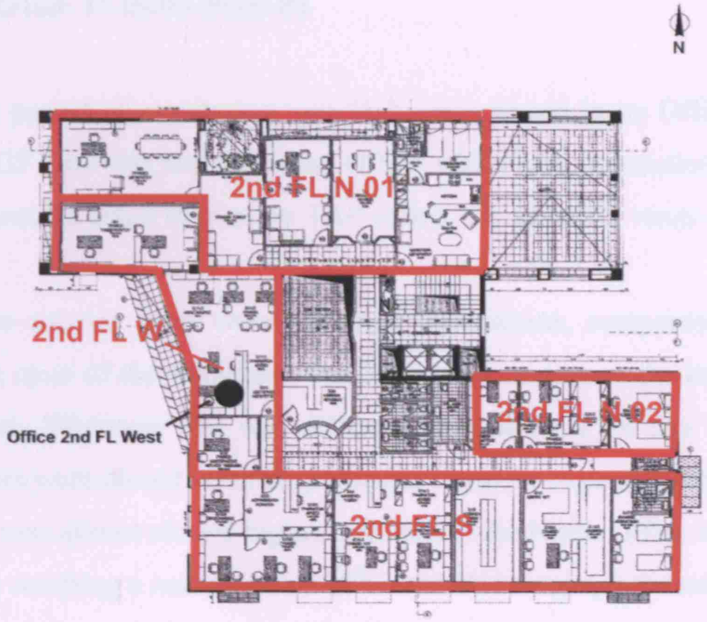


Figure 4.3. Monitoring-2nd Floor zones

Date	Floor	Zone	Office
17.05.05-30.05.05	GF	GF TAP	GF TAP 01
30.05.05-02.06.05	GF	GF S	GF S
02.06.05-10.06.05	GF	GF TAP	GF TAP 02
17.05.05-30.05.05	1	1st FL N 01	1st FL N
30.05.05-02.06.05	1	1st FL TAP	1st FL TAP
02.06.05-10.06.05	1	1st FL TAP	1st FL TAP
02.06.05-10.06.05	2	2nd FL W	2nd FL W

Table 4.1. Hobo locations during monitoring period

The Hobos were placed in different offices throughout the monitoring period. In this way, data for different zones can be discussed. In addition, as the TAP system is not operated properly in every case (as discussed in 4.2), comparisons can be made between an ideal case and a problematic.

▪ **Monitoring period: 17.05.05-30.05.05**

During the first period of monitoring, one Hobo was placed in an Office with TAP on Ground Floor (GF TAP 01) and one in an Office with North orientation of the 1st Floor (1st FL N). It must be noted that in the TAP office, the system's vents were blocked by furniture.

Generally in the interior there were not great fluctuations, compared to the external Temperature. In most of the weekdays, maximum temperature in the interior was lower than the external. Whenever this was different (end of week) it can be assumed that windows or doors were closed on those particular days. As expected, the Temperature in the TAP Office was almost always higher than that in the North Office by approximately 1^0C, and merely reaching a maximum of 25^0C with RH ranging between 33-60% during the occupancy schedule.

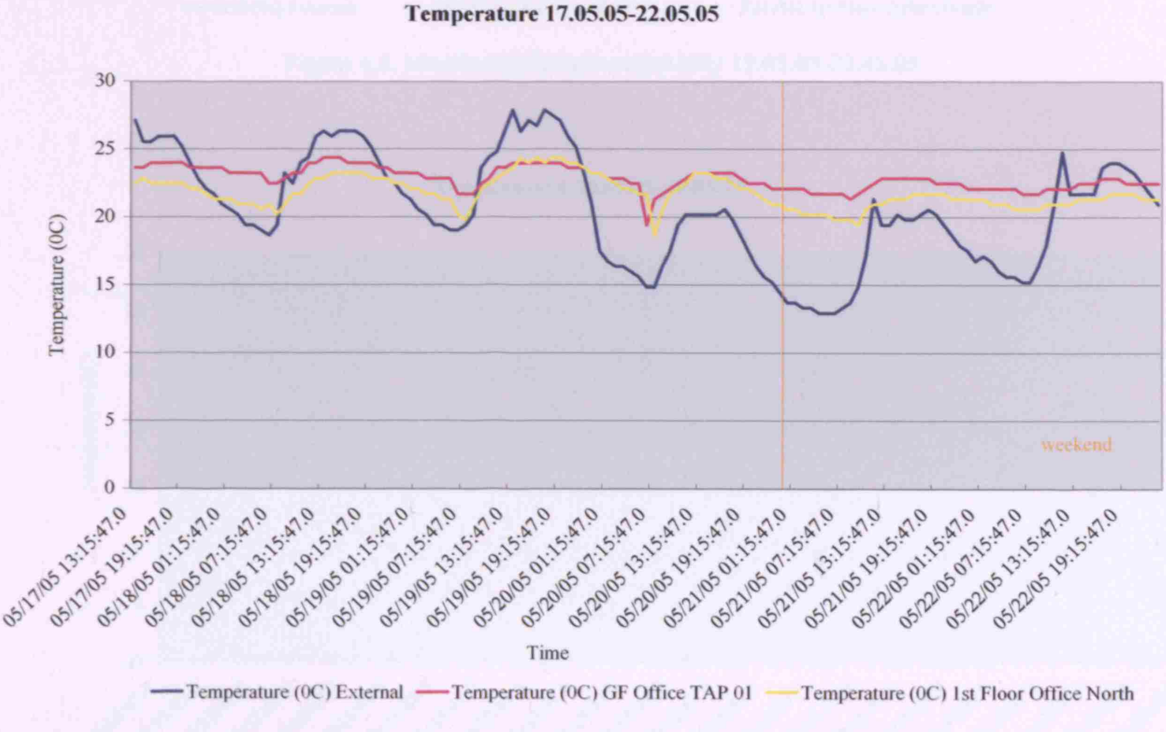


Figure 4.4. Monitoring-Temperature 17.05.05-22.05.05

Relative Humidity 17.05.05-22.05.05

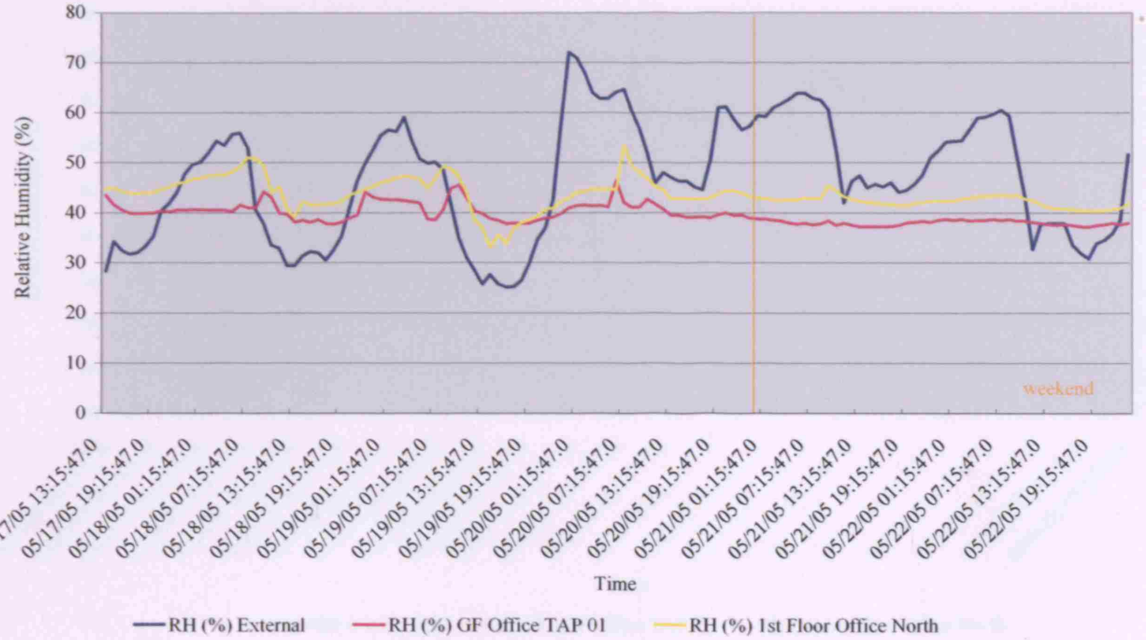


Figure 4.5. Monitoring-Relative Humidity 17.05.05-22.05.05

Temperature 23.05.05-30.05.05

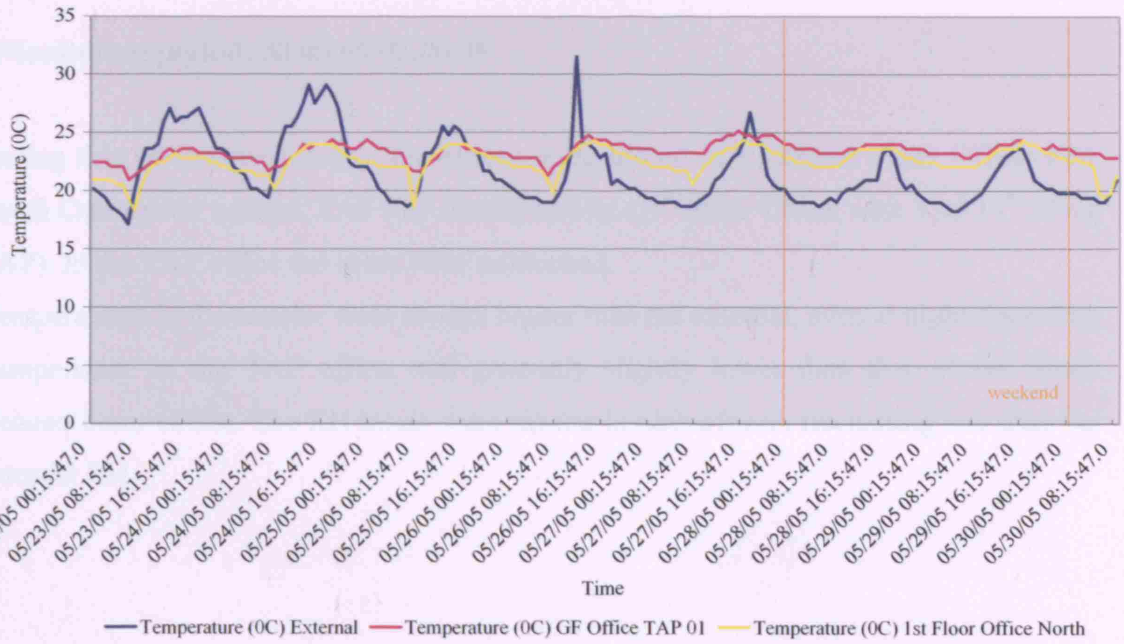


Figure 4.6. Monitoring-Temperature 23.05.05-30.05.05

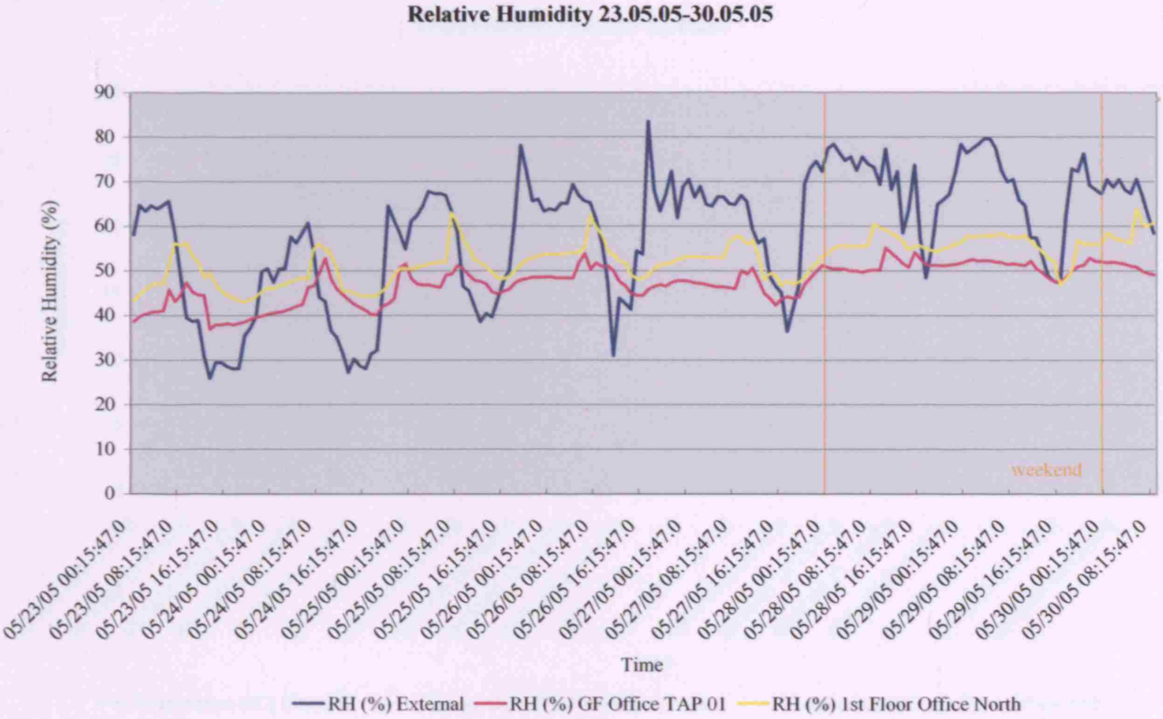


Figure 4.7. Monitoring-Relative Humidity 23.05.05-30.05.05

▪ Monitoring period: 30.05.05-02.06.05

During this period (weekdays), the Hobos were placed in a Ground Floor Office with South Orientation without TAP (GF South) and in a 1st Floor Office with TAP (1st Floor TAP). In the TAP office the vents were unblocked.

Temperatures in the interior were always higher than the external, even at night-time. The Temperature in the TAP office was generally slightly lower than that of the South Ground Floor Office. The RH levels were similar in both offices, fluctuating less than the external RH.

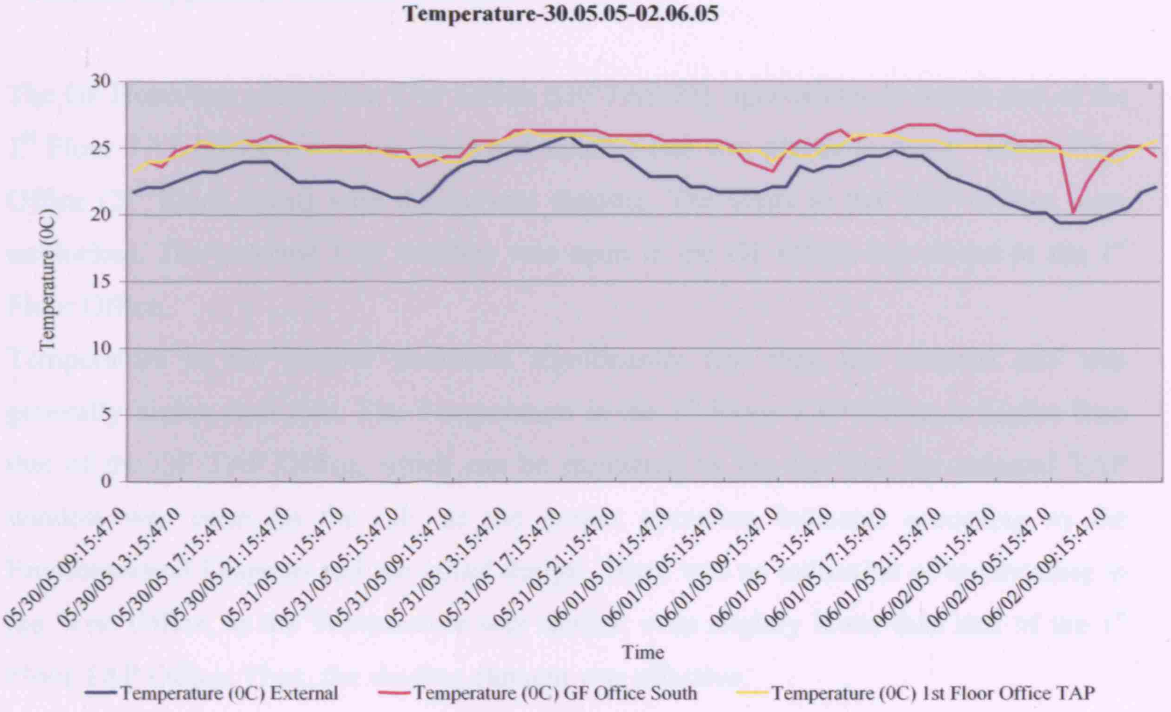


Figure 4.8. Monitoring-Temperature 30.05.05-02.06.05

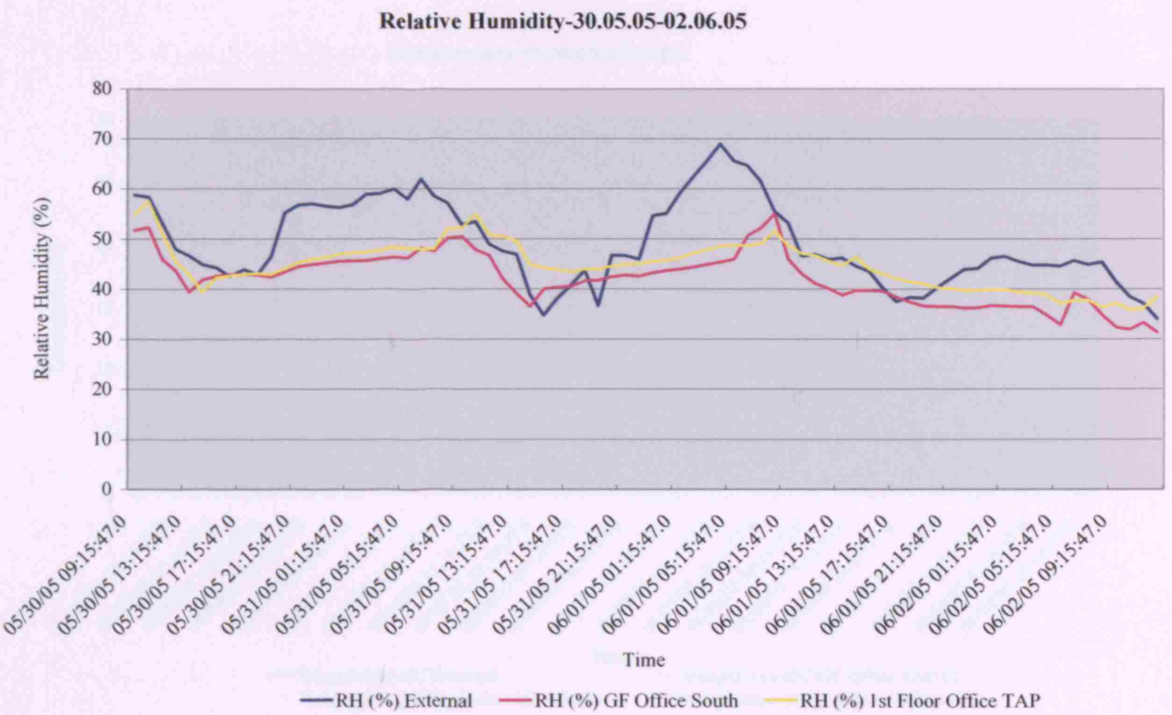


Figure 4.9. Monitoring-Relative Humidity 30.05.05-02.06.05

▪ **Monitoring period: 02.06.05-10.06.05**

The GF Hobo was placed in a TAP Office (GF TAP 02) approximately below that of the 1st Floor TAP Office (1st Floor TAP) and another one was placed in the 2nd Floor West Office (2nd Floor West) with the louvres shading. The vents in the TAP offices were unblocked. The external TAP window was open in the GF Office but closed in the 1st Floor Office.

Temperature in the interior fluctuates significantly less than the external and was generally higher than that. The Temperature in the 1st Floor TAP Office is higher than that of the GF TAP Office, which can be explained by the fact that the external TAP window was open on the GF, as the proper operation indicates according to the Environmental Diagram and the initial design. There was no indication of overheating in the West Office, as the Temperature was similar, even slightly lower than that of the 1st Floor TAP Office. Thus, the shading element was effective.

Although RH levels were high outdoors, they were more stable in the interior and in general terms lower. However, RH reached was between 35-60% during weekdays, apart from the last three days, where there the external Temperature was below 20^{0}C.

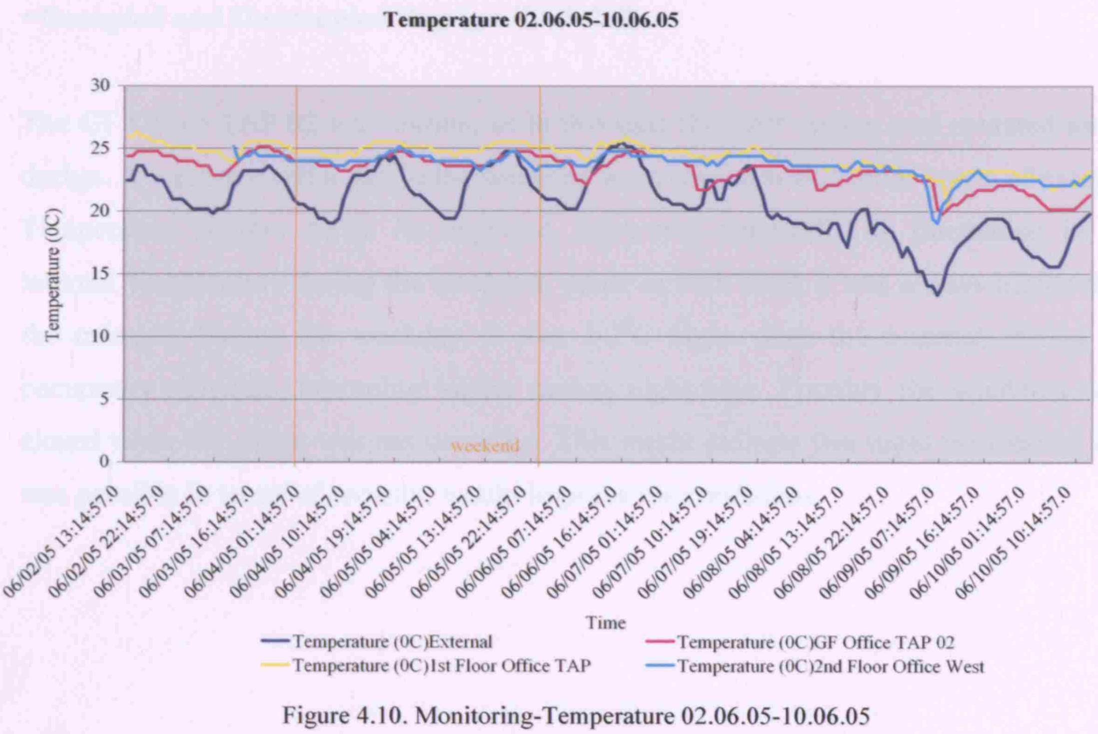


Figure 4.10. Monitoring-Temperature 02.06.05-10.06.05

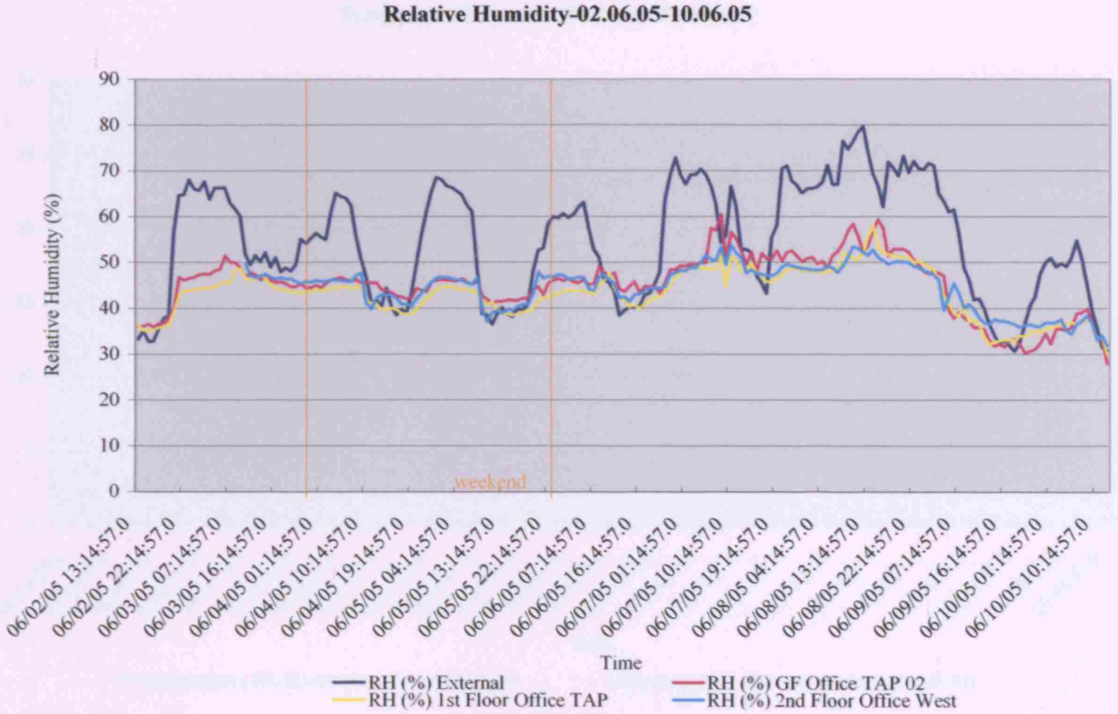


Figure 4.11. Monitoring-Relative Humidity 02.06.05-10.06.05

▪ Occupied and Unoccupied Day in a TAP Office

The GF Office TAP 02 was chosen, as in this case the TAP system was operated as the design. A weekday and a day in the weekend were chosen with similar levels of external Temperature (Figure 4.12). As expected, there was practically no fluctuation in the internal Temperature during the weekend, while in both cases it was always higher than the external. During the weekday, it was 1-2^{0}C higher than the external, during the occupancy schedule, becoming higher during night-time. Possibly the windows were closed when the office was not occupied. This might indicate that night ventilation, if it was possible in terms of security, would improve the conditions.

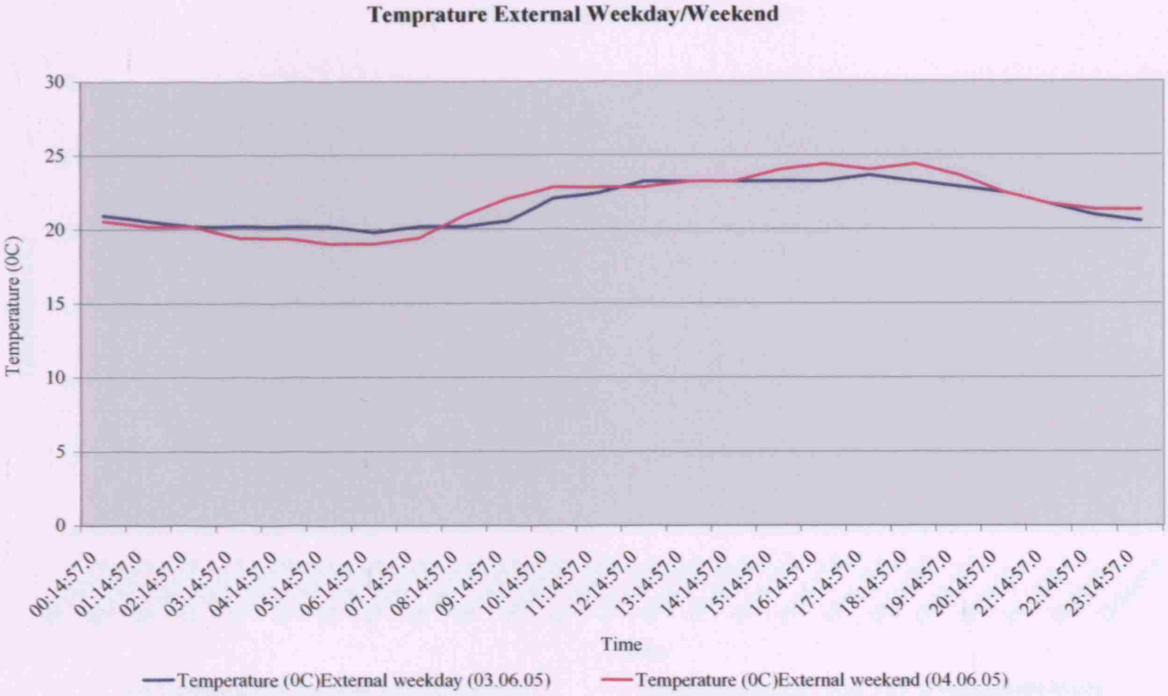


Figure 4.12. Monitoring-External Temperature Weekday/Weekend

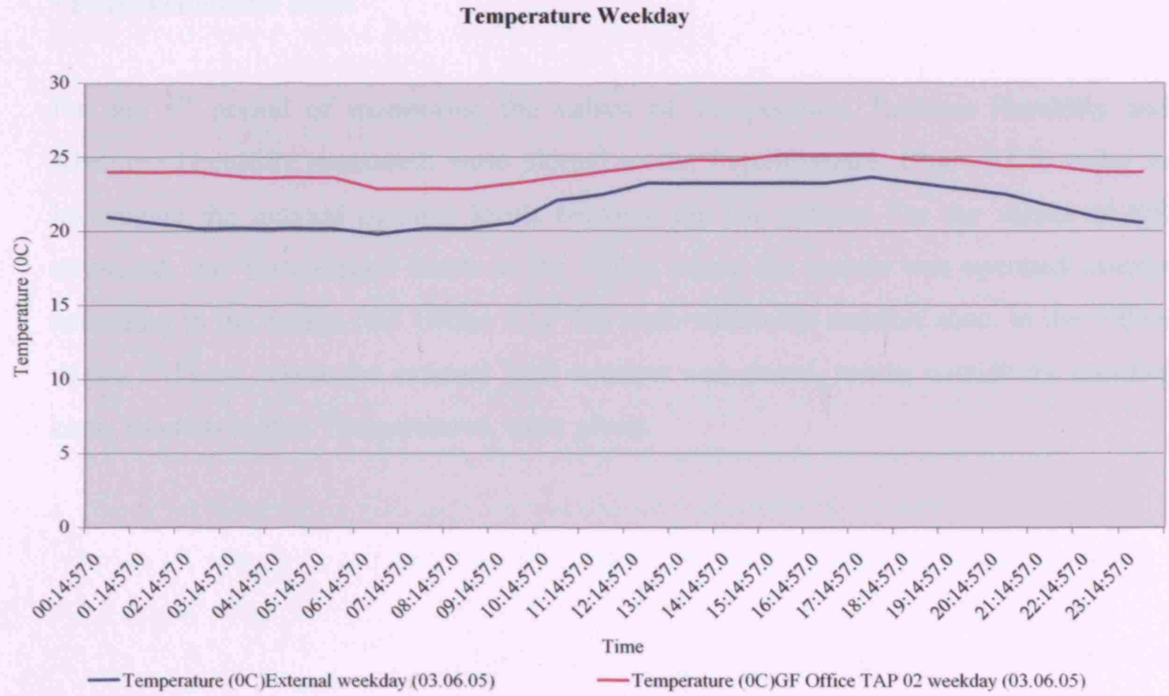


Figure 4.13. Monitoring-Temperature Weekday

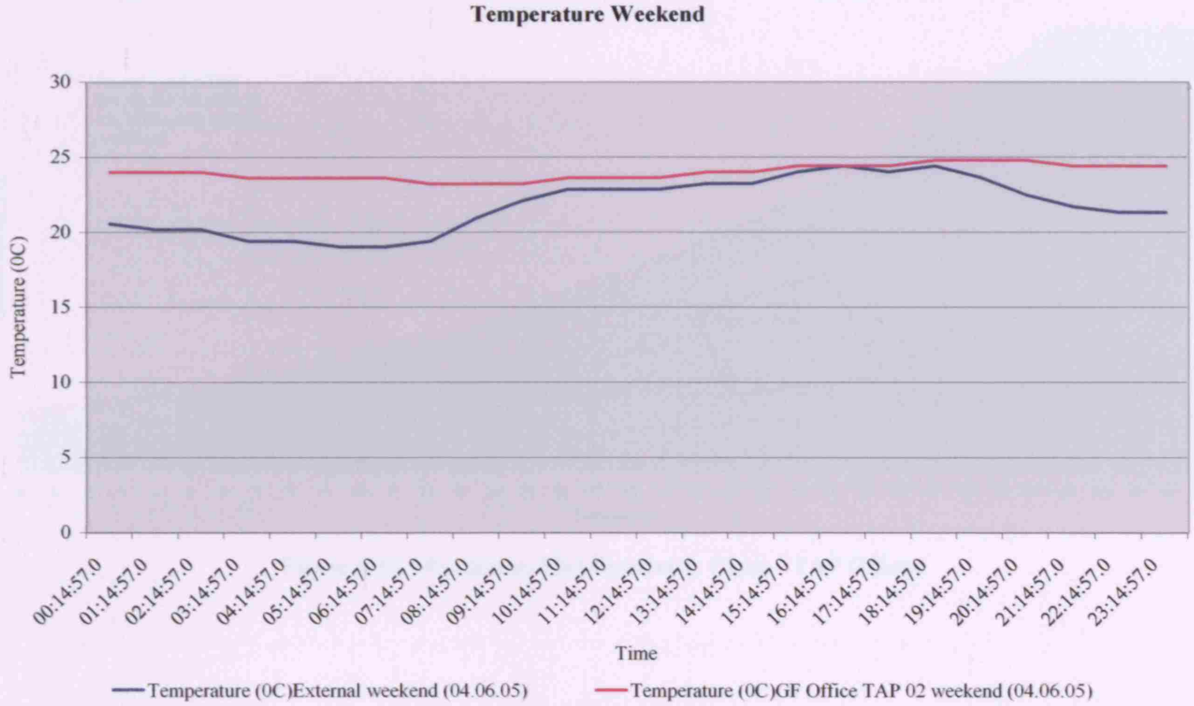


Figure 4.14. Monitoring-Temperature Weekend

▪ Phsychrometric chart

For the 3rd period of monitoring the values of Temperature, Relative Humidity and Absolute Humidity measured, were plotted to the Psychrometric Chart [1] in order to investigate the internal comfort levels between the two offices. For the values of RH measured, the Temperature levels in the Office where the system was operated exactly according to the design (GF Office TAP 02) were within the comfort zone. In the Office of the 1st Floor, where the external TAP window was closed, results outside the comfort zone, towards higher Temperatures, were given.

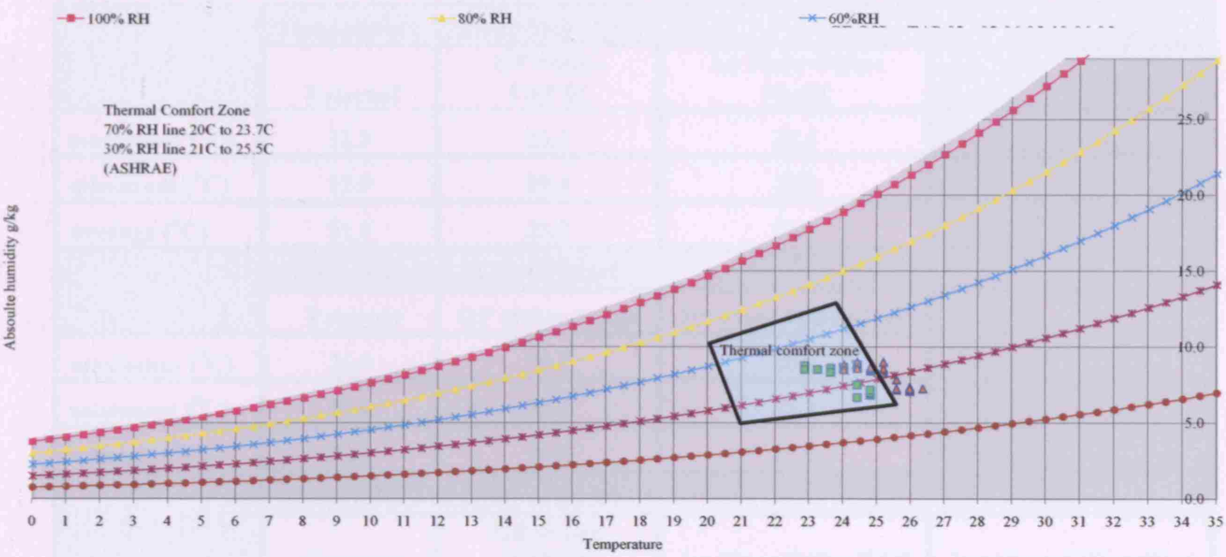


Figure 4.15. Monitoring-Phsychrometric Chart – TAP Offices

Overall, Temperatures in the North Side were lower than the external during day-time and higher during night-time without great fluctuations, as would have been expected. The Temperature monitored in the South Office was higher than the external, but this could be explained taking into account the small area of openings of the particular office. There was no significant overheating in the west side. Despite the higher external temperature during the first period of monitoring, internal Temperatures in a TAP office was similar to the pattern of the North side (during occupancy schedule) even though the system did not operate properly (vents blocked). On the other hand, during the other two periods of monitoring, Temperature levels in TAP offices were higher than the external Temperature.

These indicate that adequate ventilation is necessary in order to improve the internal Temperature levels or cooling might be required, particularly for the mid-summer period. It should be noted again that openings were under the occupants control.

Profiles of internal conditions for the whole year using computer simulation will be discussed in Chapter 5.

	Temperature 17.05.05-30.05.05			
	External	GF Office TAP 01	1st Floor Office North	
maximum (°C)	31.5	25.2	24.4	
minimum (°C)	12.9	19.4	18.3	
average (°C)	21.1	23.2	22.2	
	Temperature 30.05.05-02.06.05			
	External	GF Office South	1st Floor Office TAP	
maximum (°C)	26.0	26.7	26.3	
minimum (°C)	19.4	20.2	23.2	
average (°C)	22.7	25.3	25.0	
	Temperature 02.06.05-10.06.05			
	External	GF Office TAP 02	1st Floor Office TAP	2nd Floor Office West
maximum (°C)	25.6	25.2	26.3	25.2
minimum (°C)	13.3	19.8	20.6	19.0
average (°C)	20.6	23.3	24.4	23.6

	Relative Humidity 17.05.05-30.05.05			
	External	GF Office TAP 01	1st Floor Office North	
maximum (%)	83.5	55.1	64.0	
minimum (%)	25.2	36.9	33.2	
average (%)	53.5	44.1	48.7	
	Relative Humidity 30.05.05-02.06.05			
	External	GF Office South	1st Floor Office TAP	
maximum (%)	69.0	55.0	57.7	
minimum (%)	34.1	31.4	35.9	
average (%)	49.1	42.0	44.8	
	Relative Humidity 02.06.05-10.06.05			
	External	GF Office TAP 02	1st Floor Office TAP	2nd Floor Office West
maximum (%)	79.7	60.5	58.1	53.8
minimum (%)	30.7	28.0	30.0	31.8
average (%)	54.5	45.1	43.3	44.8

Table 4.2. Summary of results from monitoring

4.4. QUESTIONNAIRE SURVEY

The occupants were asked to evaluate the environmental conditions in the building by answering a questionnaire (Appendix B) on a typical weekday (06.06.05). 21 out of 33 people responded to the survey (approximately 63.6%), the majority of which were male, as it is a Police Station.

Figure 4.16. Questionnaire Survey-Gender

The location of people was categorized according to the zoning of Chapter 4.3.

Approximately 50% found the conditions in terms of thermal comfort neutral. The majority of the answers of the rest, were on the positive scale (slightly warm – hot).

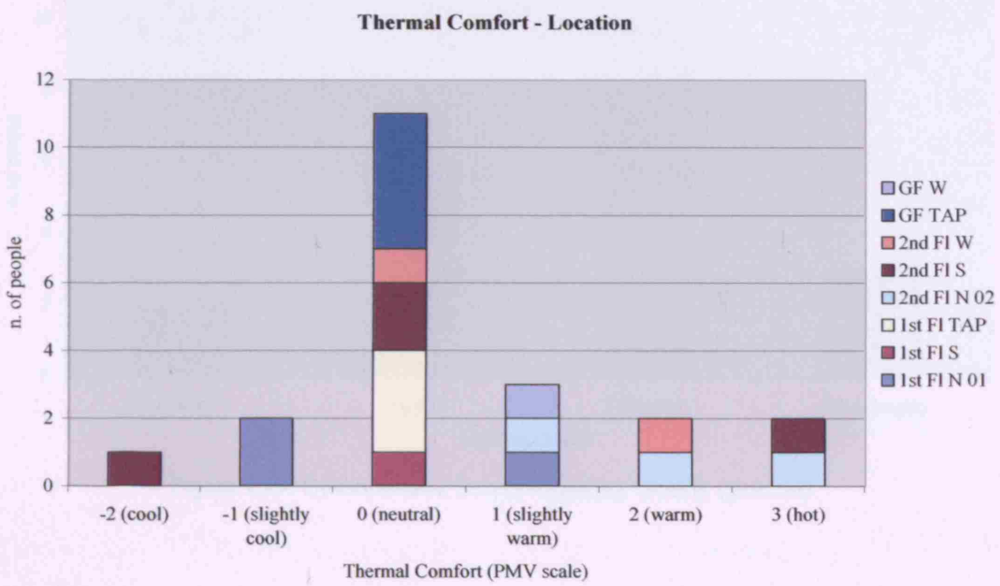


Figure 4.17. Questionnaire Survey-Thermal Comfort – Location

In terms of lighting, 10/21 people stated that it was bright, both in the office where they were seated (local lighting) and in the building generally.

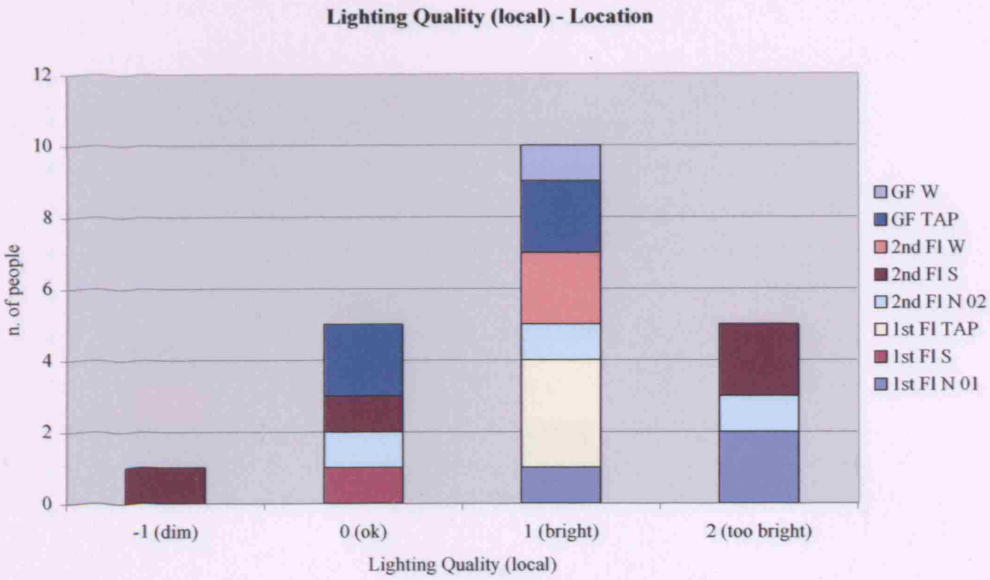


Figure 4.18. Questionnaire Survey-Lighting Quality (local) - Location

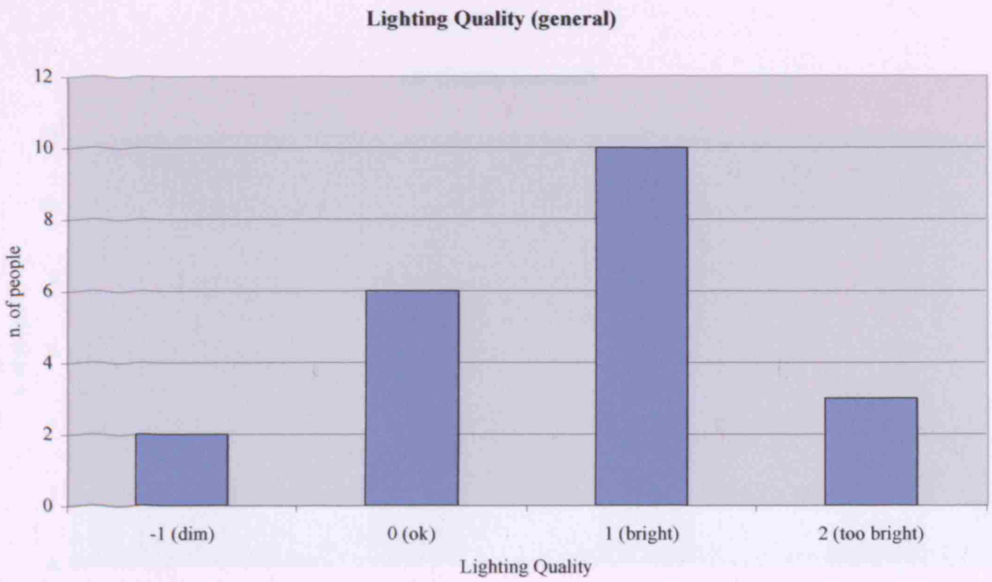


Figure 4.19. Questionnaire Survey-Lighting Quality (general)

A similar pattern of answers was given in questions regarding the air quality. Most of the people evaluated the air quality as ok-good, both locally and generally in the building.

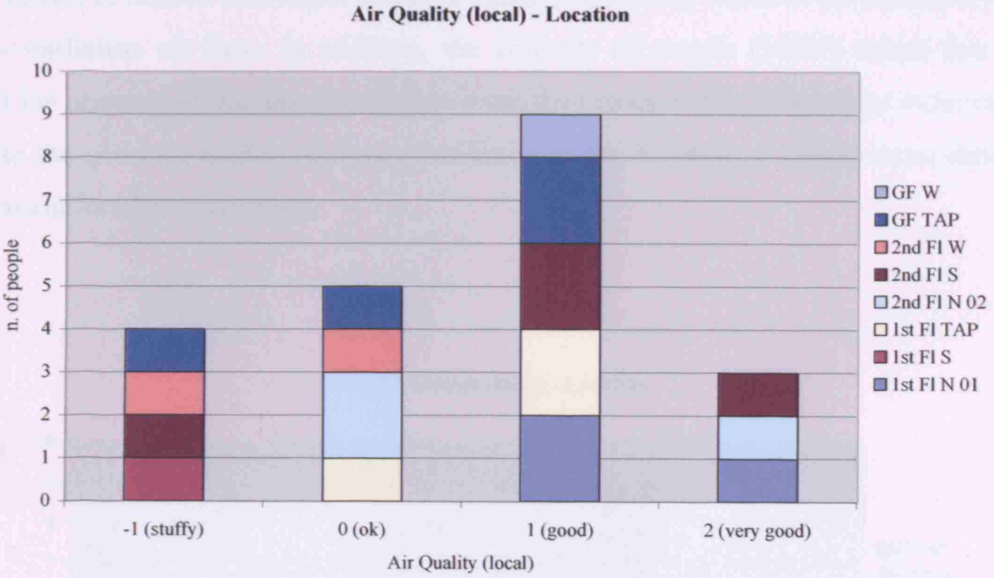


Figure 4.20. Questionnaire Survey-Air Quality (local)-Location

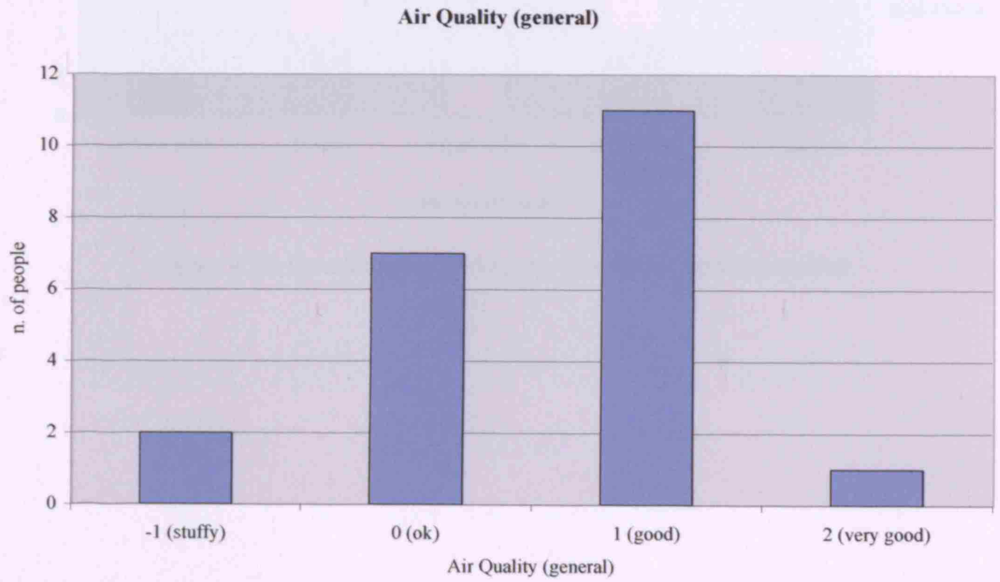


Figure 4.21. Questionnaire Survey-Air Quality (general)

In terms of air movement, despite the fact that 9/21 people stated that it was slightly draughty locally, the majority (13/21) rated the air movement in the building generally as just right. It must be noted that almost all the people that responded to the survey (18/21) were seated in offices with either North or South orientation, which is the direction of the cross-ventilation air flow. In addition, the majority of people (14/21) stated that they adjust the opening of the nearest window more than twice a day. This might indicate that despite the good air quality of cross-ventilation in the building, it might cause draughts and uncomfortable conditions.

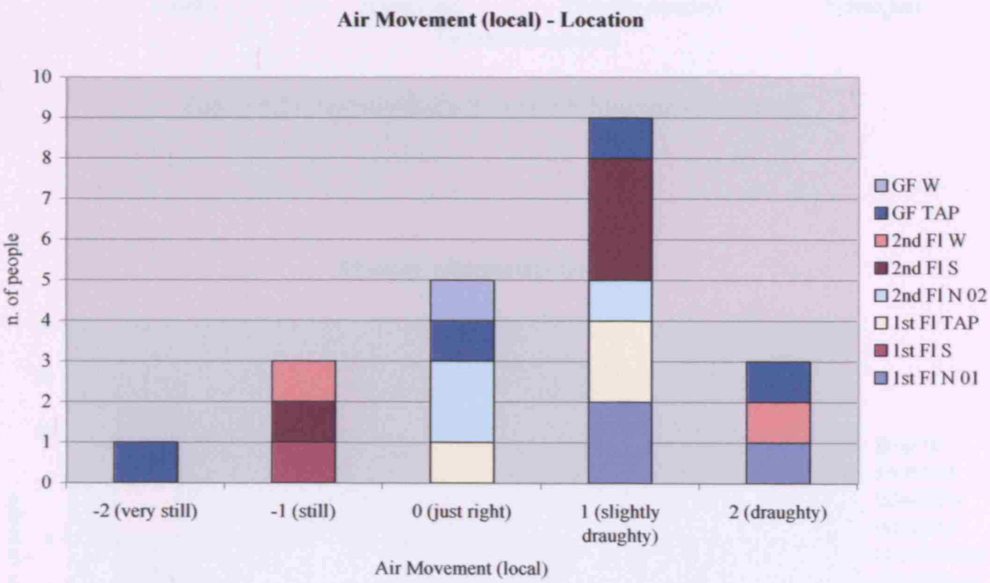


Figure 4.22. Questionnaire Survey-Air Movement (local)-Location

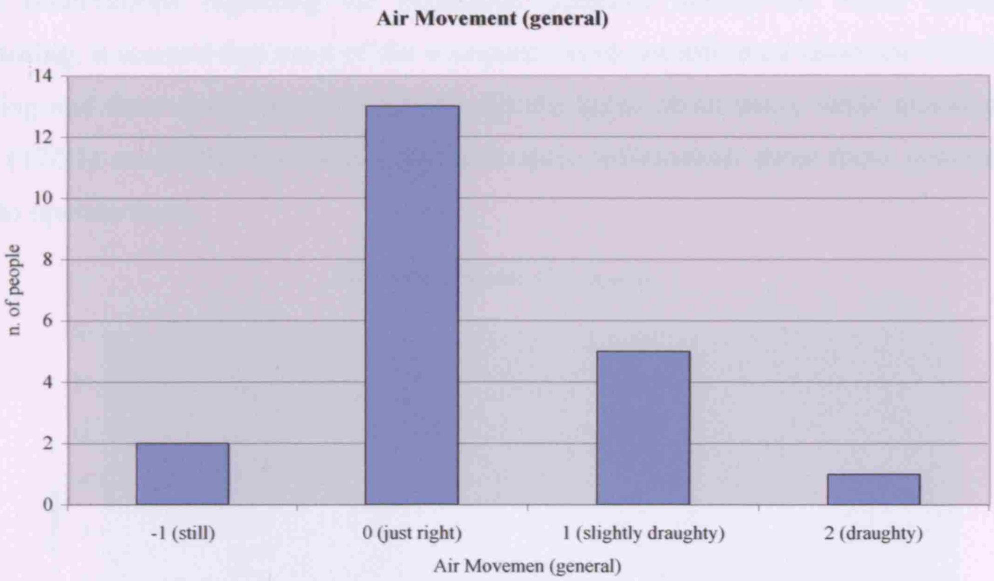


Figure 4.23. Questionnaire Survey-Air Movement (general)

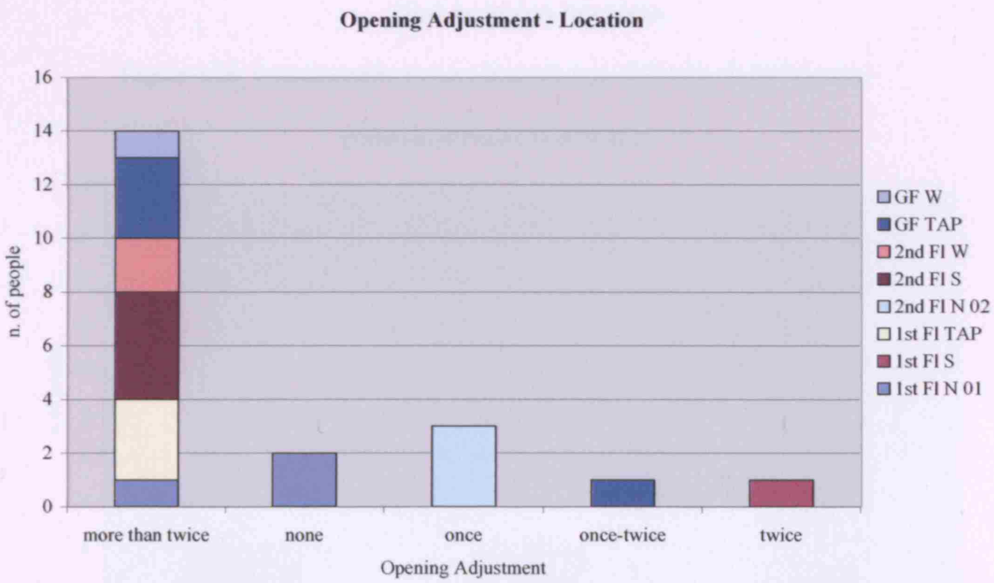


Figure 4.24. Questionnaire Survey-Opening adjustment-Location

From observations regarding the occupants behavior during the whole period of monitoring, it seemed that most of the occupants were not informed about the PSS in the building and their operation.14/21 people did not know about them, while almost all of them (17/21) stated that it would be useful to have information about these systems and how to operate them.

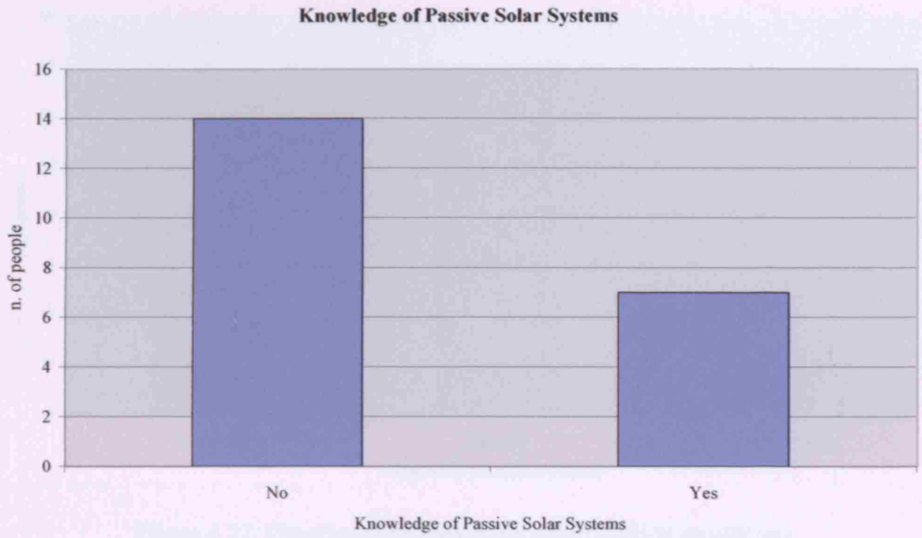


Figure 4.25. Questionnaire Survey-Knowledge of Passive Solar Systems

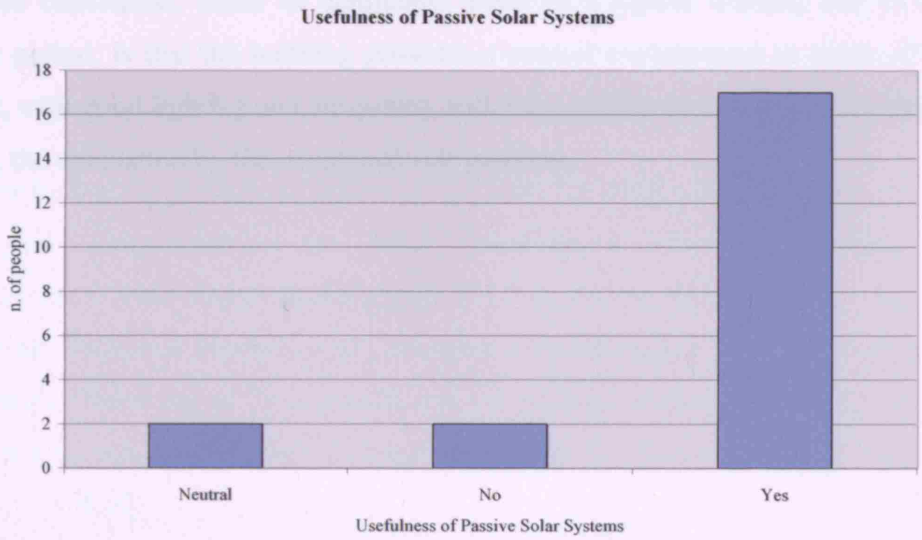


Figure 4.26. Questionnaire Survey-Usefulness of Passive Solar Systems

Most of the people (14/21) evaluated the general working conditions in the building as good. There were no negative answers. Additional comments from informal interviews as well, were made about problems caused by moisture or leak in the building, but these are related to the quality of construction.

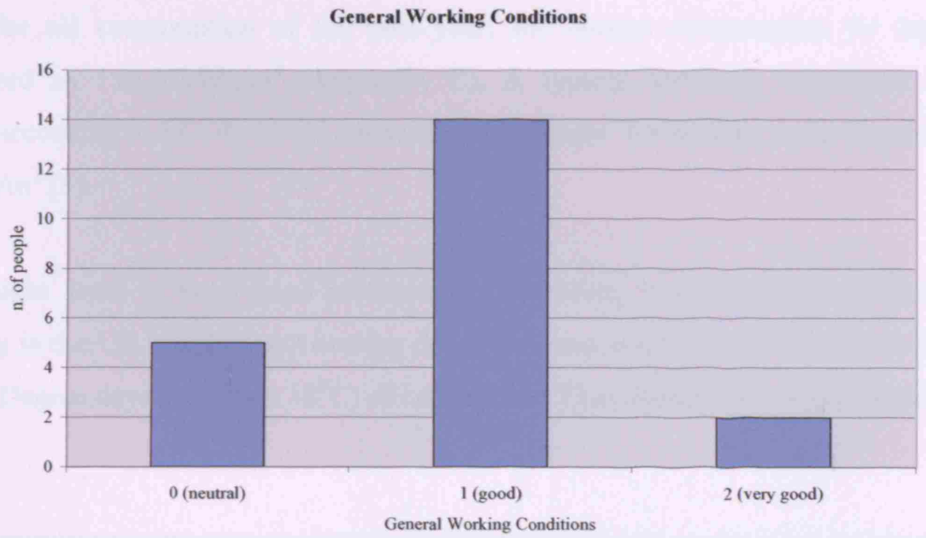


Figure 4.27. Questionnaire Survey-General working conditions

A general conclusion, based on comments made on a typical working day of an early summer period, is that the building provides a neutral environment in terms of thermal comfort, with good lighting and air quality and some problems in terms of air movement. Overall, the evaluation by the occupants was positive.

4.5. ENERGY CONSUMPTION – EVALUATION

Data about the energy consumption for heating were given – oil consumption of the past year (October-April). There was not available data about the electricity consumption.

From the oil consumption of the past year, the energy consumption for heating is calculated as 150.85kWh/m^2 (Appendix C). A typical Naturally Ventilated Cellular Office according to ECON 19 [2] consumes 151kWh/m^2 for heating and a Good Practice 79kWh/m^2 [3].

This might seem to be a good performance. However, it is important to note that a building in the UK has different heating demands compared to one in Greece. In the table below, Degree days (based on 18^{0}C) of London and Thessaloniki can be compared. [4].

City	Latitude	Degree Days (18°C)	Average Minimum temperature (°C)
London	51^0	2830	-2
Thessaloniki	40^0	1725	-5

Table 4.3. Degree Days of London and Thessaloniki

Data concerning the energy performance of Public Buildings in Greece are provided by the project "Renovation of the public buildings of Central Macedonia for the improvement of their energy performance" [5], carried out by Domotechniki SA Public and Private Technical Projects, the Laboratory of Contruction and Building Physics of the Aristotle University of Thessaloniki and the Hellenic Public Real Estate Corporation and funded by the program SAVE (Specific Actions for Vigorous Energy Efficiency) of the EU of 1994 [6].

30 buildings in total were surveyed in different cities of the Prefecture of Central Macedonia (Figure 4.27), including the old building of the Police Station of Kilkis [7]. This sample corresponds to 14% of the Public Office Buildings in Central Macedonia [8]:

Figure 4.28, 4.29, Maps of Greece and of the Prefecture of Central Macedonia

Category	Time of Construction	Percentage over sample	Insulation	Central Heating
A	before 1950	13%	No	No (during construction)
B	1950-1980	70%	No	Yes
C	after 1980	17%	Yes	Yes

Table 4.4. Categories and profiles of Public Office Buildings of Central Macedonia surveyed

In Order to evaluate this data, some information on the construction, services systems and operation are given in Appendix D.

It is characteristic that 88.8% of the energy consumption in the buildings that were surveyed represents the energy consumption for heating (Figure 4.28) [9].

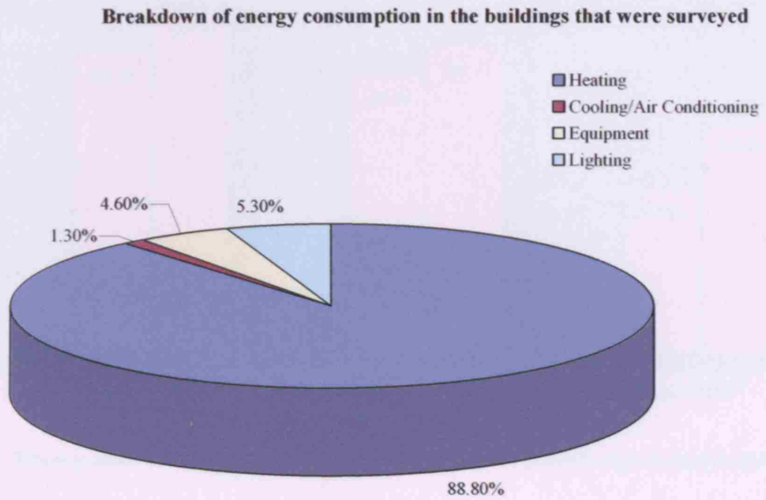


Figure 4.30. Breakdown of energy consumption of Public Office Buildings of Central Macedonia surveyed

From the following graph, the energy consumption for heating of the Police Station of Kilkis (150.85kWh/m^2) is relatively lower than the average energy consumption of Category B buildings and 50% higher than that of recently built ones. This can be explained by the bad operation of the building (TAP system, high thermostat temperature levels). However, it is approximately half of that of the old Police Station building of Kilkis (285.57 kWh/m^2) [10].

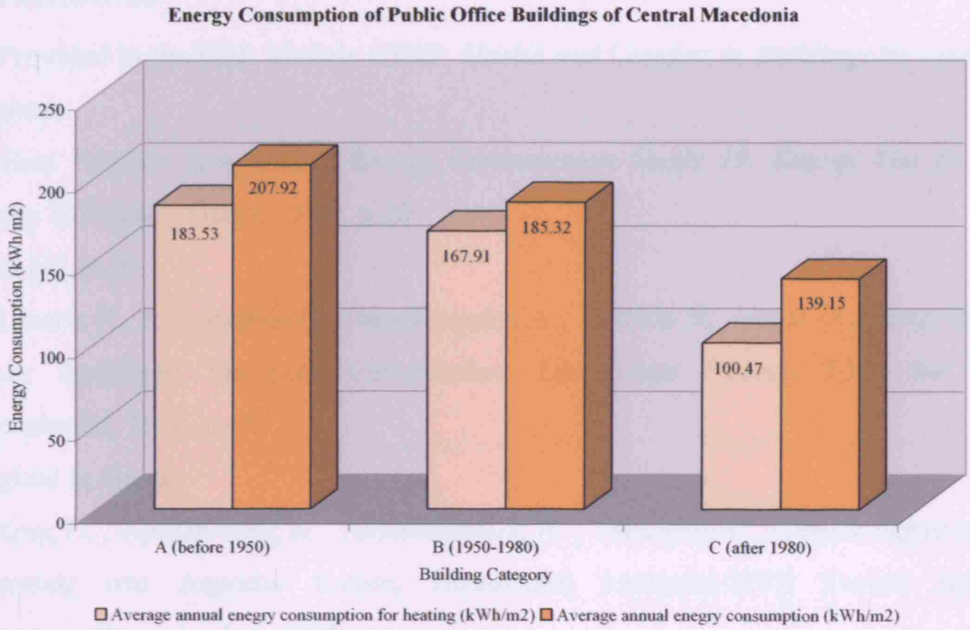


Figure 4.31. Energy Consumption of Public Office Buildings of Central Macedonia

The very small percentage of energy consumption for cooling -1.3%- (Figure 4.28) can be justified by the fact that cooling is not widely applied in Public Office Buildings and thermal comfort levels are almost in every case not acceptable [11]. In addition, the relatively low percentage of office equipment energy consumption (4.6%) is expected to be increased by 8-10 kWh/m^2 annually, because of Office equipment improvements. [12]

Summing up, an increase in the energy consumption of Public Office Buildings due to improvements in the services, equipments and thermal comfort levels is expected to occur [13]. The average consumption of 198 kWh/m^2 [1] might rise to 250 kWh/m^2 [14] Effective measures in order to prevent this can be made in terms of reducing the energy consumption for heating, without compromising the occupants thermal comfort [15].

In this context, the extent to which the actual energy consumption for heating of the Police Station of Kilkis, could be reduced if the PSS were operated according to the design is investigated with computer simulation and discussed in Chapter 5.

1. Referring to mid 1990's, when the survey was carried out.

REFERENCES

[1] Provided in the EDE Module *GE02: Health and Comfort in Buildings* for coursework purposes

[2] Best Practice Programme, *Energy Consumption Guide 19: Energy Use In Offices*, Energy Efficiency Office, 2000, p.20

[3] as [1], p.20

[4] Liveris P., Aravantinos D., Papadopoulos A., Tsakiris N., *Guide of Energy Saving in Public Buildings*, European Commission- Directorate General XVII for Energy, Thessaloniki, 1996, p.15

(original in Greek:

Λιβέρης Π. , Αραβαντινός Δ. , Παπαδόπουλος Α. , Τσακίρης Ν. , Οδηγός Εξοικονόμησης Ενέργειας στα Δημόσια Κτίρια, Ευρωπαϊκή Επιτροπή-XVII Γενική Διεύθυνση Ενέργειας, Θεσσαλονίκη, 1996)

[5] as [4]

[6] as [4], p.11,12

[7] as [4], p.14

[8] as [4], p.14

[9] as [4], p.17,18

[10] as [4], Table 4, p.20

[11] as [4], p.18

[12] as [4], p.18, 19

[13] as [4], p.19

[14] as [4], p.19

[15] as [4], p.19

SOURCES OF ILLUSTRATIONS

FIGURES

Figure 4.1. based on the plans of the building of the Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

Figure 4.2. as Figure 4.1

Figure 4.3. as Figure 4.1

Figure 4.26. http://www.expedia.com/pub/agent.dll?qscr=over&rfrr=-357 [August 2005]

Figure 4.27. http://www.lonelyplanet.com/worldguide/destinations/europe/greece [August 2005]

Figure 4.28. Liveris P., Aravantinos D., Papadopoulos A., Tsakiris N., *Guide of Energy Saving in Public Buildings*, European Commission- Directorate General XVII for Energy, Thessaloniki, 1996, p.18, Figure 6,
(original in Greek:
Λιβέρης Πάνος, Αραβαντινός Δημήτρης, Παπαδόπουλος Άγις, Τσακίρης Νίκος, Οδηγός Εξοικονόμησης Ενέργειας στα Δημόσια Κτίρια, Ευρωπαϊκή Επιτροπή XVII Γενική Διεύθυνση Ενέργειας, Θεσσαλονίκη, 1996)

Figure 4.29. as Figure 4.28, p.20, Table 4

TABLES

Table 4.3. based on, Liveris P., Aravantinos D., Papadopoulos A., Tsakiris N., *Guide of Energy Saving in Public Buildings*, European Commission- Directorate General XVII for Energy, Thessaloniki, 1996, p.15, Table 3
(original in Greek:
Λιβέρης Πάνος, Αραβαντινός Δημήτρης, Παπαδόπουλος Άγις, Τσακίρης Νίκος, Οδηγός Εξοικονόμησης Ενέργειας στα Δημόσια Κτίρια, Ευρωπαϊκή Επιτροπή XVII Γενική Διεύθυνση Ενέργειας, Θεσσαλονίκη, 1996)

Table 4.4. as Table 4.3, p.14, Table 2

5. ANALYSIS – COMPUTER SIMULATION

5.1. OBJECTIVES

The differences between the constructed building and the initial design, with important bioclimatic features (atrium, clerestory windows) not constructed according to the design and the problems observed in operation (blocking the TAP system) have undoubtedly an impact on the buildings energy performance and thermal comfort levels. This can be investigated with computer simulation using TAS software [1], aiming to determine the buildings ideal energy performance.

5.2. METHODOLOGY

5.2.1. Model

A 3D model of the building was created.

Figure 5.1. Simulation-3D Model

Because of the TAP system and the air flow pattern in the adjacent offices, the Ground and 1st Floor (where these systems are found), are divided vertically in two zones, lower (Bottom) and upper (Top). The lower zone's height is 2.3m and any results referring to these floors correspond to that zone, also referred to as occupied zone.

The atrium was designed with opening windows and the ceiling below the clerestory windows unblocked, as in the initial design. The TAP systems were created in the Offices where they are installed in the existing building. The basement floor was added as well.

5.2.2. Weather file

As a weather file for the city of Kilkis was not available, the weather file of Thessaloniki was used, a city which is approximately 50km away from Kilkis (Figure 2.1, 2.2)

5.2.3. Constructions

The building elements are constructed according to construction details (Chapter 2.5) and plans [2] and can be seen in detail in Appendix E-1. As for the TAP wall, it is not possible to create in TAS a construction with both transparent and opaque layers. Therefore, the TAP wall was created as a separate wall and glazing with a gap between them. The minimum gap that could be achieved in the model was 170mm which does not correspond to the actual gap (50mm).

5.2.4. Zones

The model was zoned according to the spaces use and orientation in the following zones (Figures 5.2-4), as in the monitoring analysis (Chapter 4.3).

- Offices N (North)
- Offices S (South) – no TAP
- Offices TAP
- TAP gap (the area between the external wall of the TAP Offices and the glazing)
- Offices W (West)
- Atrium
- Corridor
- Terrace

Storage rooms, rest rooms, stairs, the cells and spaces of temporary use (gym, events-meeting space, café) were omitted from the analysis, in order to focus on the Office spaces. The treated floor area, thus, corresponds to the area of the spaces that were zoned and simulated.

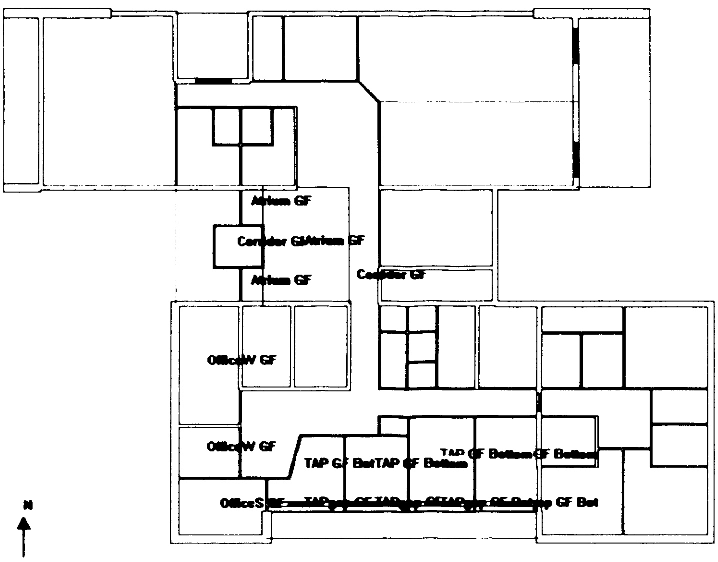


Figure 5.2. Simulation-GF zones

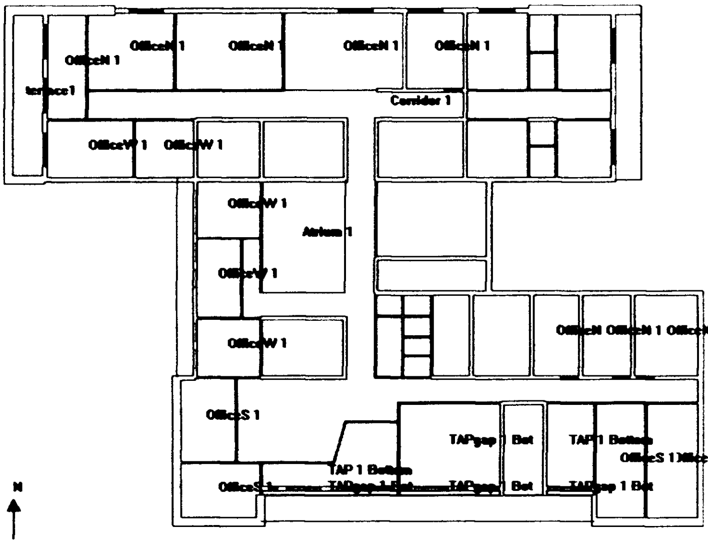


Figure 5.3. Simulation-1st Floor zones

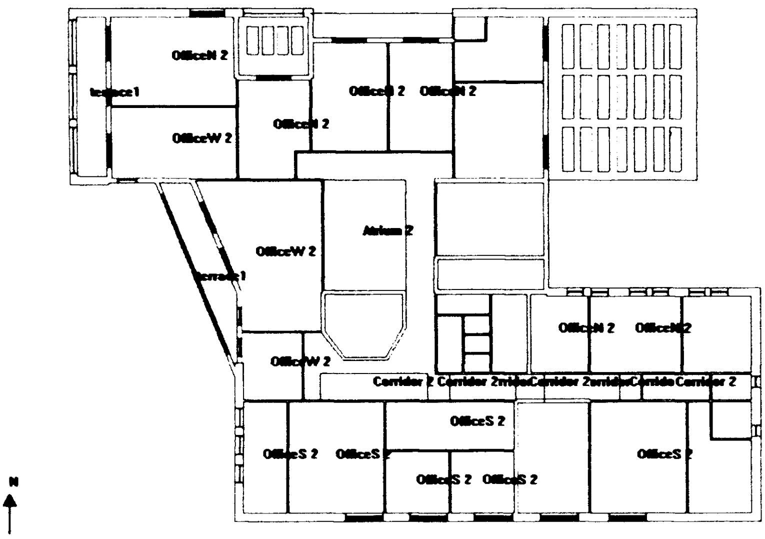


Figure 5.4. Simulation-2nd Floor zones

5.2.5. Internal Conditions – Schedules

Internal gains and conditions in the different zones can be seen in the Table below.

Internal Conditions				
Zones		weekday 8am-4pm	weekday after 4pm	weekend
Office N Office W	Infiltration	0.5 ach		0.5 ach
	Lighting gains	8.0 W/m^2		0 W/m^2
	Occupancy sensible	5.8 W/m^2		0 W/m^2
	Occupancy latent	2.3 W/m^2		0 W/m^2
	Equipment	9.0 W/m^2		0 W/m^2
TAP bottom	Infiltration	0.5 ach		0.5 ach
	Lighting gains	4.0 W/m^2		0 W/m^2
	Occupancy sensible	5.8 W/m^2		0 W/m^2
	Occupancy latent	2.3 W/m^2		0 W/m^2
	Equipment	9.0 W/m^2		0 W/m^2
TAP top	Infiltration	0.5 ach		0.5 ach
	Lighting gains	4 W/m^2		0 W/m^2
	Occupancy sensible	0 W/m^2		0 W/m^2
	Occupancy latent	0 W/m^2		0 W/m^2
	Equipment	0 W/m^2		0 W/m^2
Office S	Infiltration	0.5 ach	0.5 ach	0.5 ach
	Lighting gains	8.0 W/m^2	3.0 W/m^2	3.0 W/m^2
	Occupancy sensible	5.8 W/m^2	0.18 W/m^2	0.18 W/m^2
	Occupancy latent	2.3 W/m^2	0.07 W/m^2	0.07 W/m^2
	Equipment	9.0 W/m^2	3.0 W/m^2	3.0 W/m^2
Common spaces (Corridor-Atrium)	Infiltration	0.5 ach	0.5 ach	0.5 ach
	Lighting gains	8.0 W/m^2	3.0 W/m^2	3.0 W/m^2
	Occupancy sensible	5.8 W/m^2	0.18 W/m^2	0.18 W/m^2
	Occupancy latent	2.3 W/m^2	0.07 W/m^2	0.07 W/m^2
	Equipment	9.0 W/m^2	3.0 W/m^2	3.0 W/m^2

Table 5.1. Simulation-Internal Conditions

It was assumed that internal gains from lights and equipment were of medium range (8 W/m^2 and 9 W/m^2 respectively, according to CIBSE Applications Manual AM10 [3]. Gains from people were calculated according to the number of occupants. Calculations can be seen in Appendix E-2. Gains from people were lower in the zones were the building is occupied after 4pm (South Offices), corresponding to the Officers on duty. For the same reason, gains from lights and equipment were lower, with values that correspond to low gains [4]. For the TAP Offices, as they were vertically divided in two zones in the model, all the internal gains were in the lower zone, apart from those form lights, where the value was divided.

5.3. SOLAR SHADING

Sun position was simulated for December 21 and June 21. As shown from the following figures, the TAPs are completely shaded during summer, while sun is unobstructed during winter.

9am

10pm

12pm

14pm

16pm

Figure 5.5. Simulation-Solar shading- December 21-South Elevation

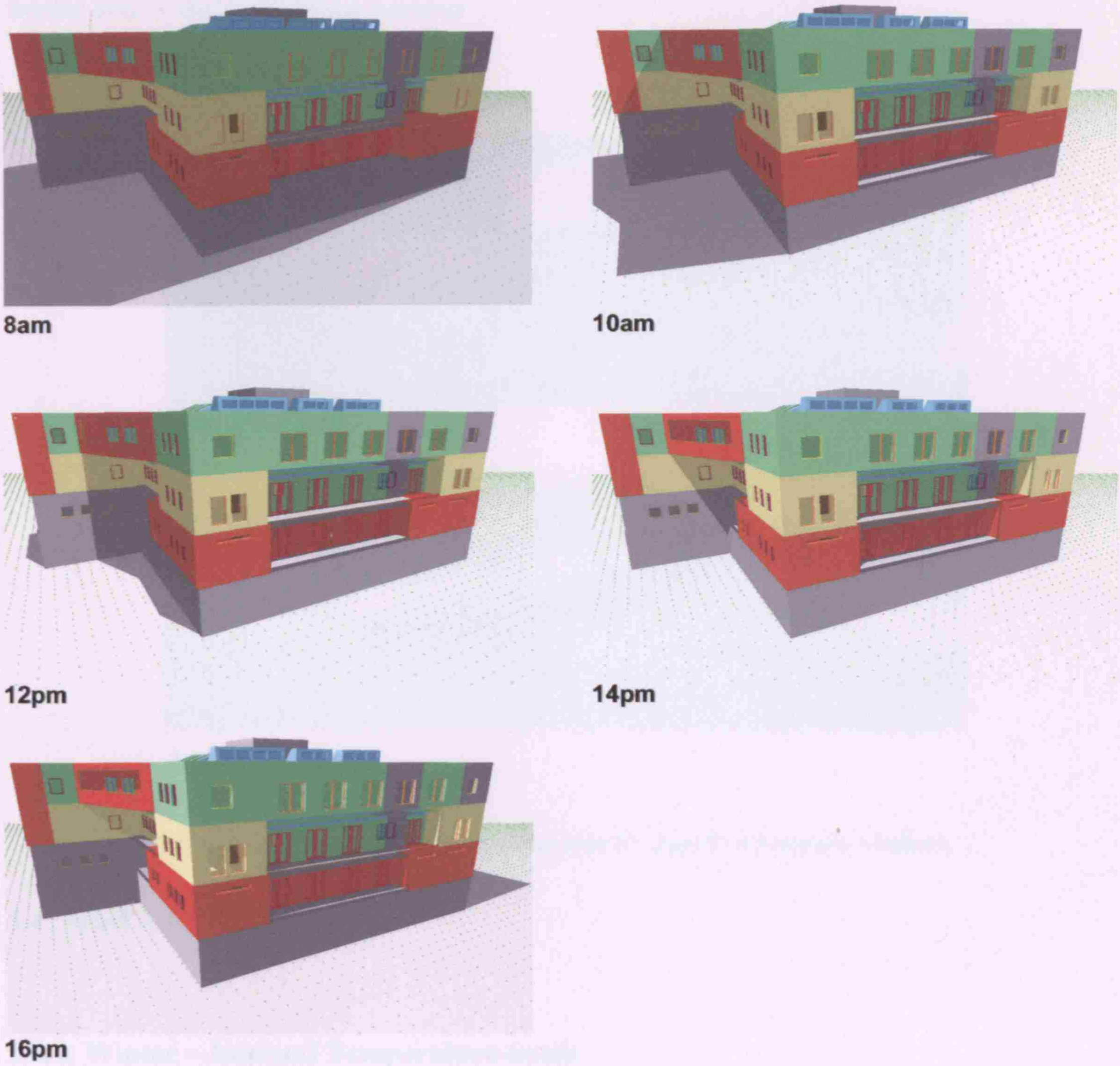
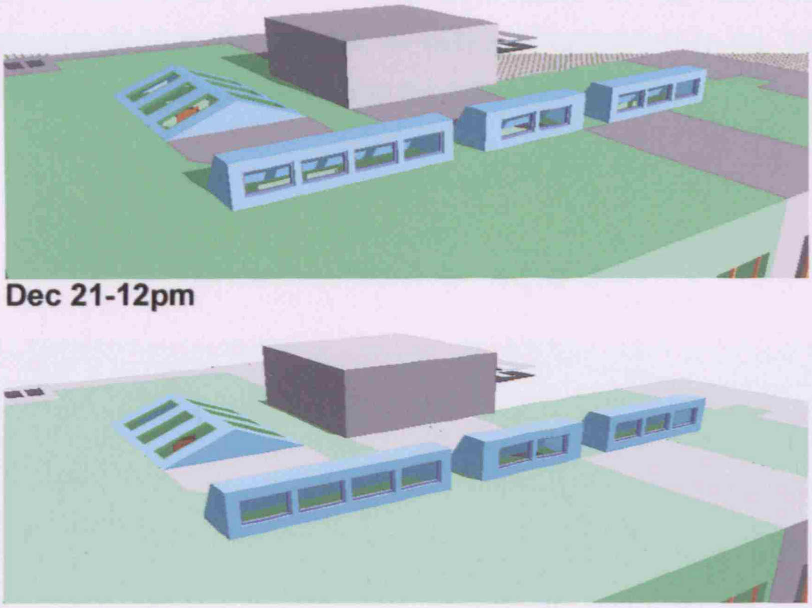


Figure 5.6. Simulation-Solar shading- June 21-South Elevation

In the same way, sun penetrates the interior through the Clerestory windows during winter and is blocked during summer



Dec 21-12pm

June 21-12pm

Figure 5.7. Simulation-Solar shading-Dec 21, June 21-Clerestory windows

5.4. SIMULATIONS

5.4.1. Winter – Internal Temperature levels

The building was simulated for Days 29-42 (January 29 - February 11). External temperatures were similar to those during the end of December.

▪ Model 1

The building was simulated with internal doors closed and Vents on TAP walls open at all times. Temperatures in the TAP Offices (occupied zone) were significantly higher than the external. Temperatures in South Offices and North Offices were lower than that of the TAP Offices by approximately 2^0C and 4^0C, respectively.

▪ **Model 2**

The building was simulated with Vents on TAP walls operating as in the design. There was no difference, in the TAP offices, which could be explained by the areas of the glazed doors in the offices (heat losses), investigated in the next model. Internal Temperatures compared to the external, as well as Temperature in the TAP Offices in relation to Global Radiation can be seen in the following graphs.

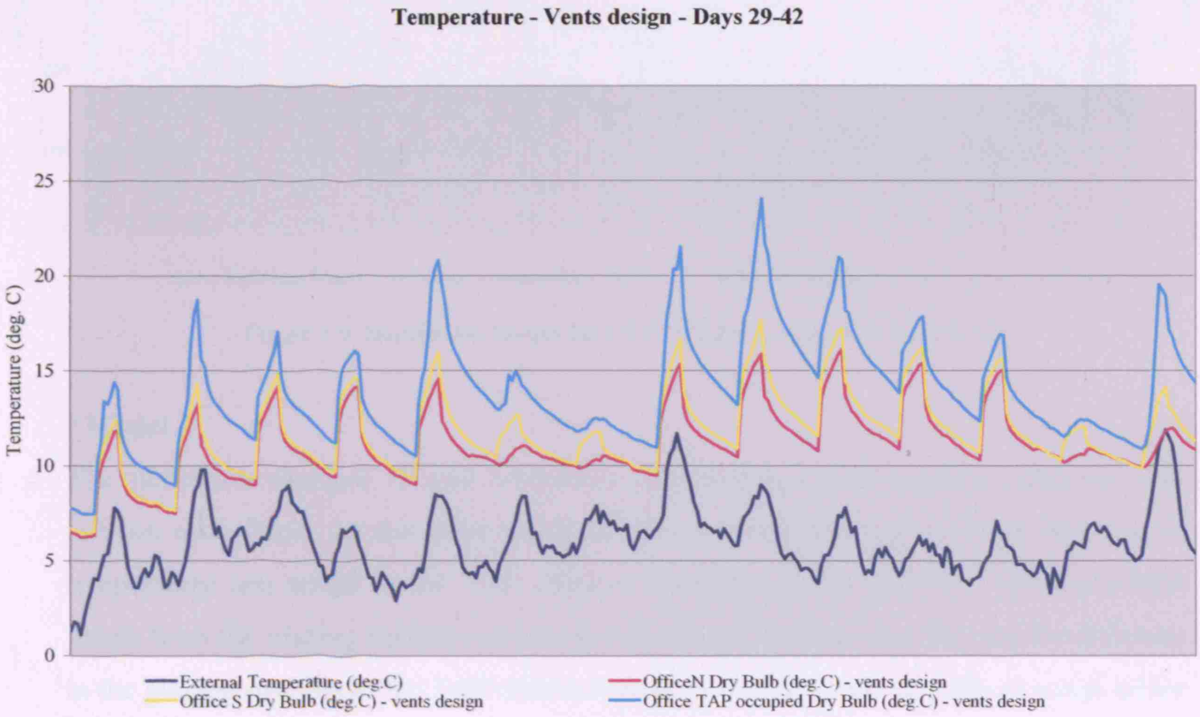


Figure 5.8. Simulation-Temperature-Vents design-Days 29-42

The Temperature in each zone is the average of Temperatures on every floor of that zone

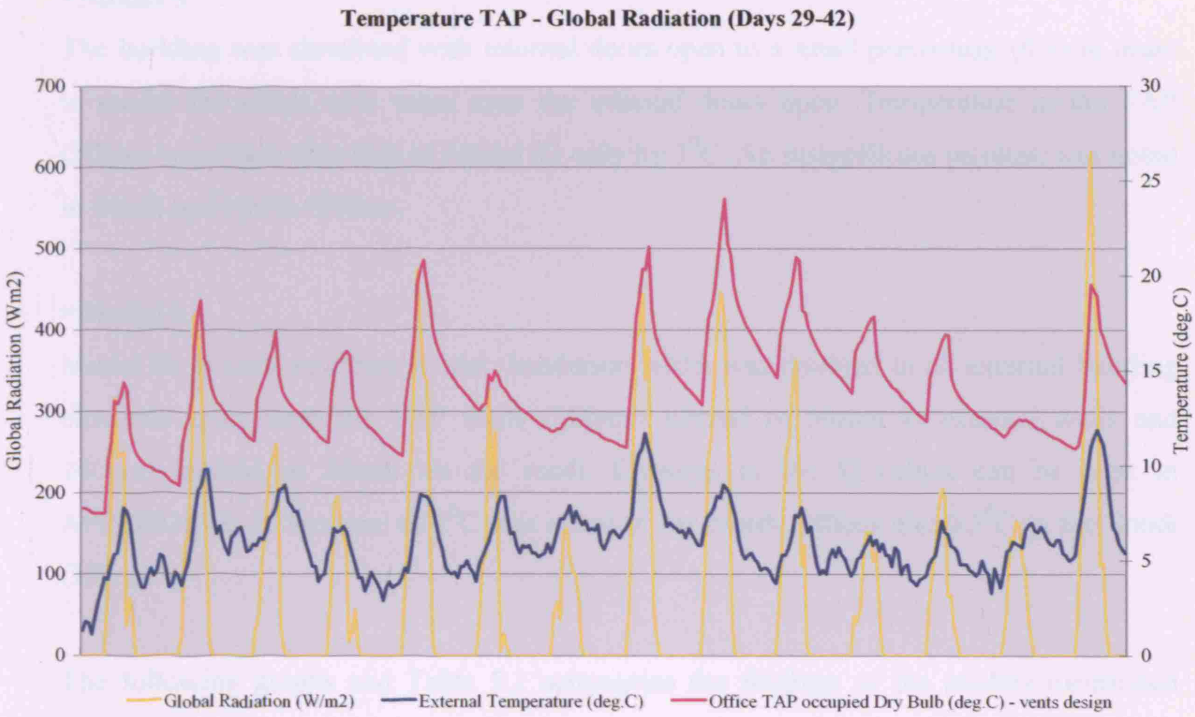


Figure 5.9. Simulation-Temperature TAP-Global Radiation (Days 29-42)

▪ Model 3

The model was changed. Glazed TAP doors were replaced with windows. Only one was left (on each floor), so that there could be access to the balcony. A slight decrease in temperature was noted in the TAP offices. Therefore, there were not significant heat losses from the glazing surfaces as assumed in the previous model. Instead, the decrease in the glazing surfaces of the TAP offices had as consequence the decrease in temperature possibly due to decrease in direct solar gains.

▪ Model 4

The building was modelled with the internal doors open, to see to what extent the spaces with no TAP are affected by the PSS. There was an important decrease in the TAP Offices temperature (by approximately 1- 4^0C) while in North Offices, a very small increase (by approximately 0.5^0C).

▪ **Model 5**

The building was simulated with internal doors open to a small percentage (0.1) in order to model the effect with vents over the internal doors open. Temperature in the TAP Offices was lower than that of Model 02 only by 1^0C. An insignificant increase was noted in South and North Offices.

▪ **Model 6**

Model 02 is used as a base model. Insulation width was doubled in all external building elements apart from the TAP walls (100mm instead of 50mm in external walls and 140mm instead of 70mm on the roof). Changes in the U-Values can be seen in APPENDIX E-1. Increase of 1^0C was noted in the North Offices and 0.5^0C in the South Offices.

The following graphs and Table 5.2 summarise the findings of the models mentioned above.

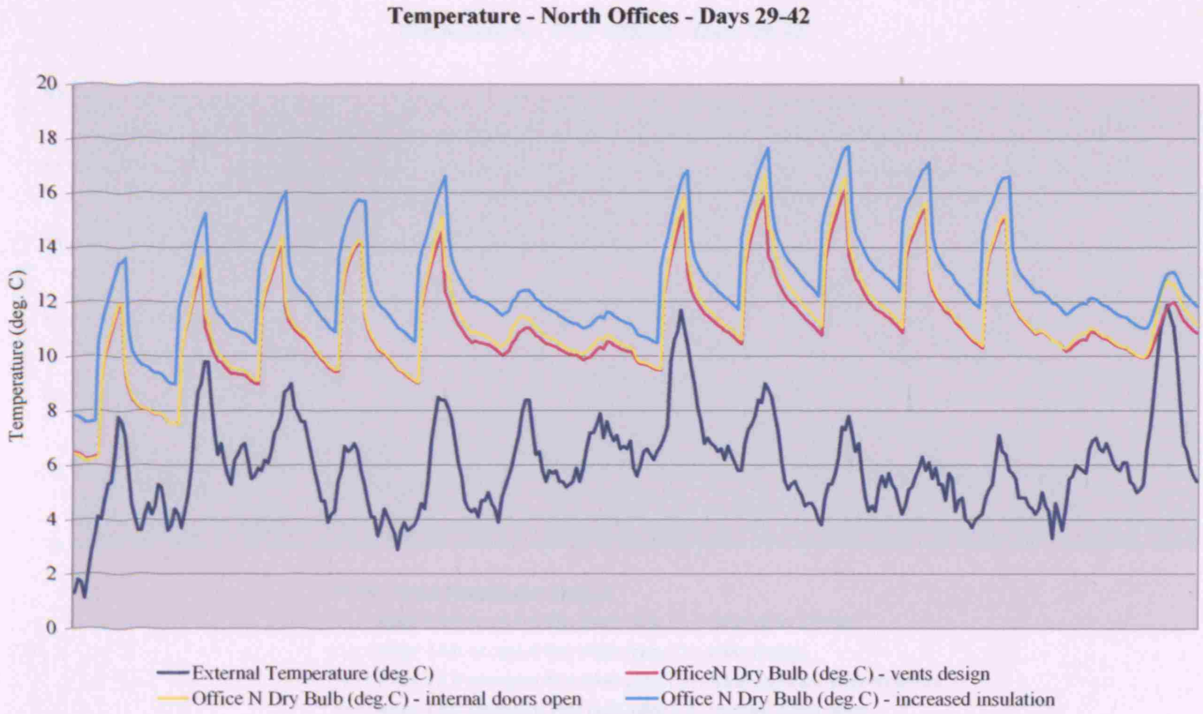


Figure 5.10. Simulation-Temperature North Offices-Days 29-42

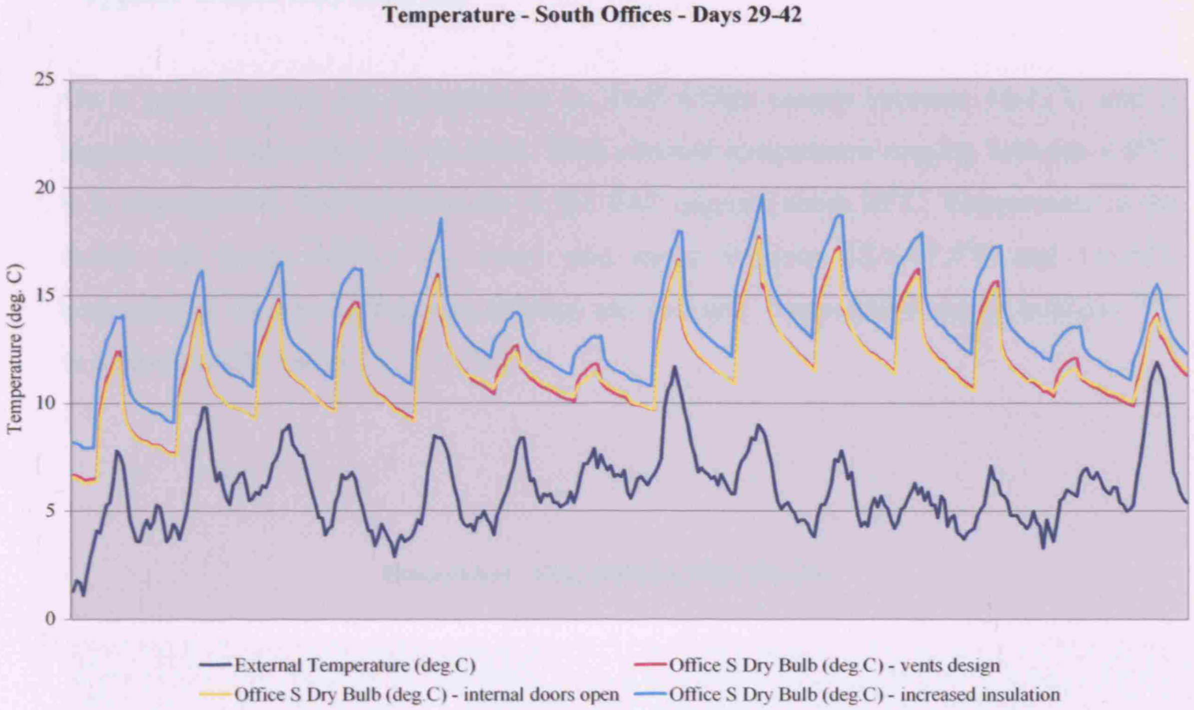


Figure 5.11. Simulation-Temperature South Offices-Days 29-42

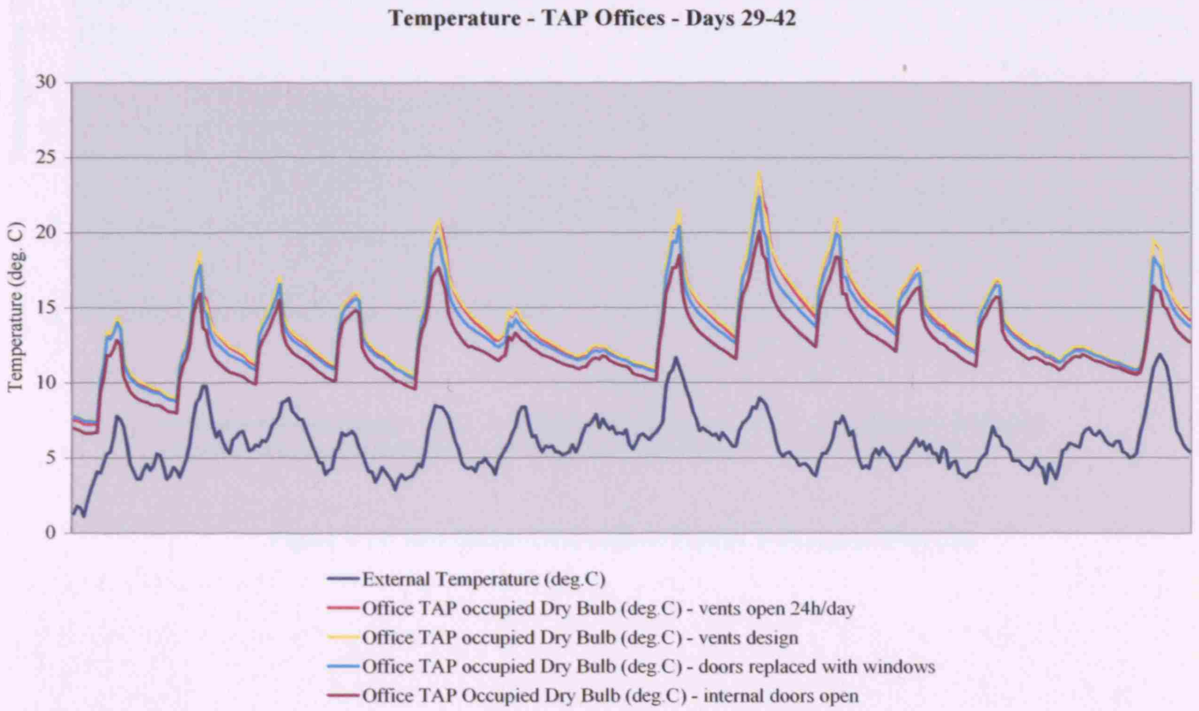


Figure 5.12. Simulation-Temperature South Offices-Days 29-42

▪ **Typical Winter Day (Day 38)**

On a typical winter day Temperature in TAP Office ranges between 14-21^{0}C and is significantly higher than the external. With external temperature ranging between 4-8^{0}C, it is characteristic that temperatures in the TAP gap can reach 23^{0}C. Temperature in the South and North Offices are lower and range between 12.5-17.5^{0}C and 11-16^{0}C respectively. Difference between internal and external Temperature ranges between 7^{0}C in a North Office and 12^{0}C in a TAP.

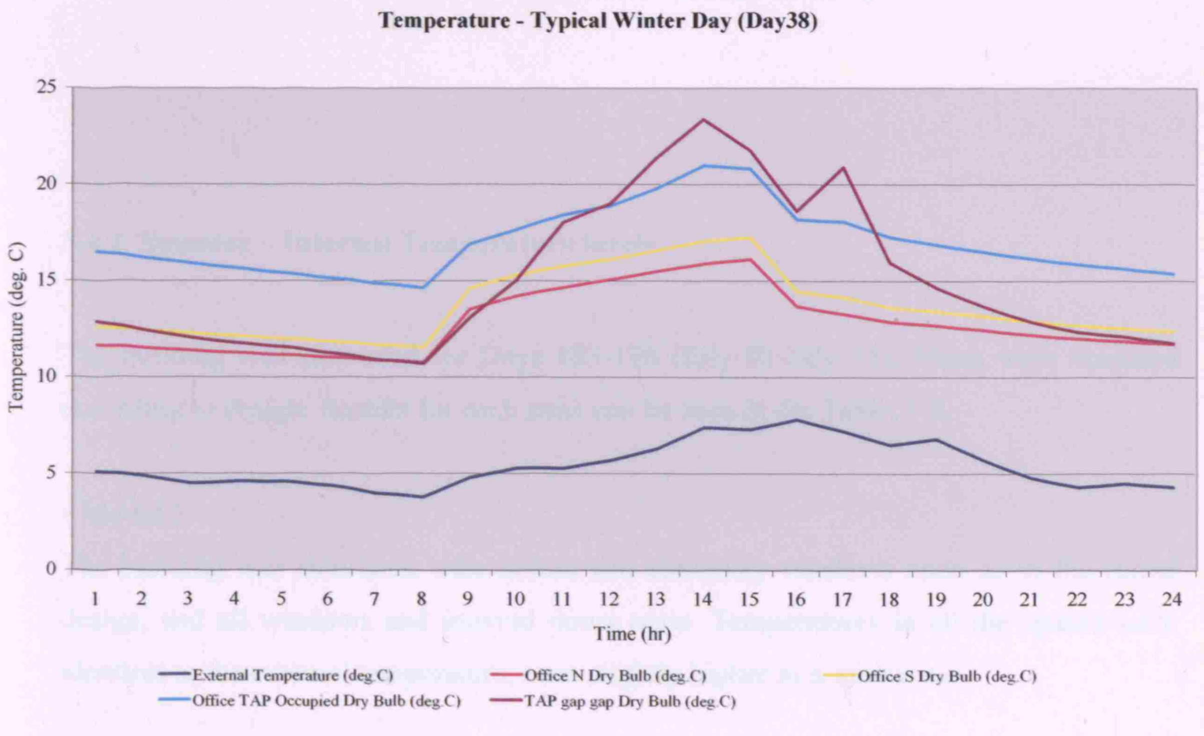


Figure 5.13. Simulation-Temperature-Typical Winter Day (Day 38)

Winter-Summary of findings												
					External Temperature range (^{0}C)		Temperature range (^{0}C)					
							N offices		S offices		TAP offices	
Model	internal doors	TAP wall vents	alterations in model	increase of insulation	min	max	min	max	min	max	min	max
1	closed	open 24h/day			1.1	11.9	6.1	16.1	6.3	19.1	7.2	25.0
2	closed	design					6.1	16.1	6.3	19.1	7.3	25.1
3	closed	design	TAP wall doors replaced with windows				6.1	16.3	6.4	19.0	7.2	22.8
4	open	design					6.0	16.7	6.3	18.5	6.6	20.1
5	open 0.1	design					6.0	16.3	6.3	19.0	7.1	23.4
6	closed	design		✓			7.2	17.9	7.8	20.6	8.0	25.6

Table 5.2. Simulation-Winter-Summary of findings

5.4.2. Summer – Internal Temperature levels

The building was simulated for Days 183-196 (July 02-July 15). Vents were operated according to design. Results for each zone can be seen in the Table. 5.3.

▪ Model 1

The building was simulated with atrium and clerestory windows open as in the initial design, and all windows and internal doors open. Temperatures in all the spaces were identical to the external temperature, even slightly higher in some cases.

▪ Model 2

The glazed doors of the TAP offices were closed, but temperatures in that zone were higher than the previous model.

▪ **Model 3**

The building was simulated with all the windows and glazed doors open. Shading features were added according to the design (Appendix E-1), which were constructed in the existing building as well. The TAPs were completely shaded by the balconies of the upper floors, as shown in Chapter 5.3. There was practically no improvement, suggesting that the effects of shading could not be simulated.

▪ **Model 4**

Model 03 was simulated keeping all the windows closed, in order to see how the building performs if external hot air is prevented from the interior. Temperatures were significantly higher in the interior.

▪ **Model 5**

In the previous model, the atrium and clerestory windows were closed. Internal temperature increased even more.

▪ **Model 6**

The lowest temperatures achieved were in the case of all windows open (Model 01). The atrium and clerestory windows were closed, as in the existing building. There was no difference in the South offices, while in the atrium and corridors, the temperature was increased on the 2nd floor and it was extremely high below the roof of the atrium and the clerestory windows.

▪ **Model 7**

The windows were closed and infiltration rate was increased from 0.5 to 1.0 ach. Atrium and clerestory windows were open and night ventilation was applied. There was no improvement as internal temperatures were identical or higher most of the time than the external.

▪ **Model 8**

Insulation levels were increased from 50mm to 100mm in external walls and from 70mm to 140mm on the roof. Changes in U-Values can be seen in Appendix E-1. Model 01 was base model. There were no improvements.

▪ **Models 9, 10**

The effect of the opening area of windows was investigated, as in Chapter 5.4.4. A very small opening area (5%) results in increase in internal Temperature, while with half the area of windows open, Temperature levels are approximately similar to those were the whole area of windows is open.

The following graphs summarize the results of the models.

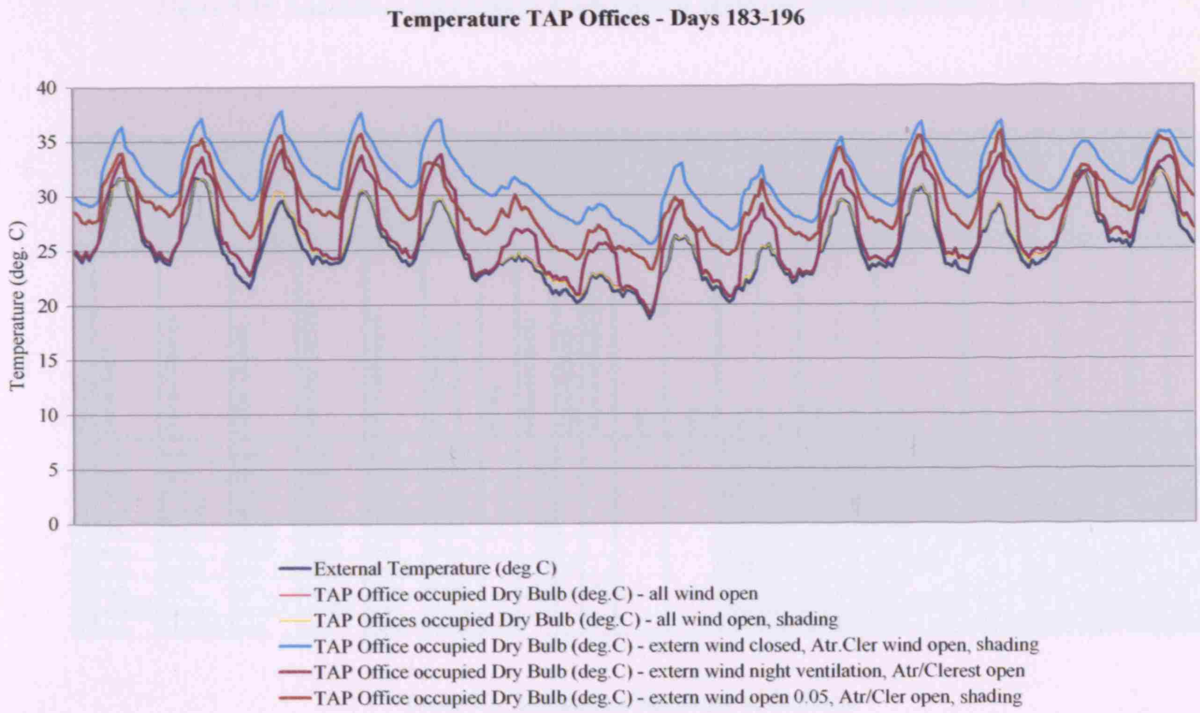


Figure 5.14. Simulation-Temperature TAP Offices-Days 183-196

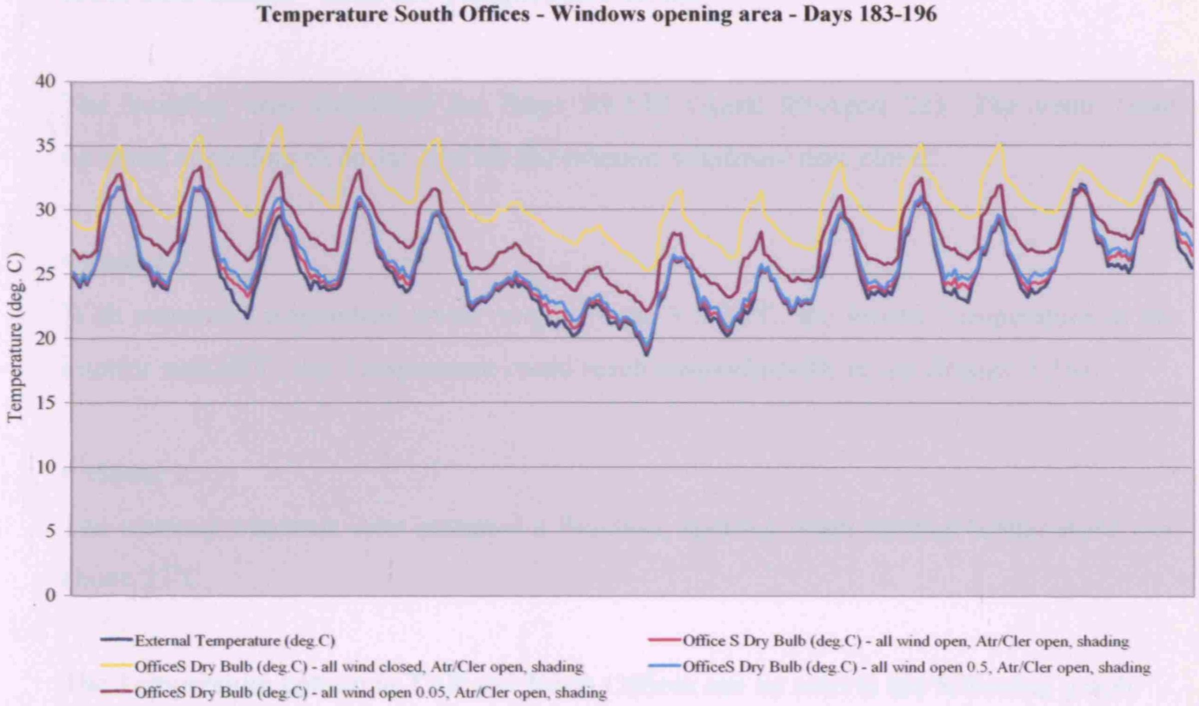


Figure 5.15. Simulation-Temperature South Offices-Windows opening area-Days 183-196

Summer-Summary of findings																								
											External Temperature range (°C)		Temperature range (°C)											
													N Offices		S Offices		W Offices		TAP Offices		Corridor		Atrium	
Model	Internal doors	External Windows	Atrium Windows	Clerestory Windows	TAP wall windows	TAP wall vents-external windows	Shading	Infiltration (ACH)	night ventilation	increase of insulation	min	max	min	max	min	max	min	max	min	max	min	max	min	max
1	open	open	open	open	open	design		0.5			18.5	32.5	18.9	32.2	19.0	32.4	18.9	32.3	19.0	32.3	18.9	32.4	19.0	32.7
2	open	open	open	open	closed	design		0.5					18.9	32.2	19.0	32.4	18.9	32.2	20.1	33.0	19.0	32.4	19.1	32.7
3	open	open	open	open	open	design	✓	0.5					18.9	32.2	19.0	32.3	18.9	32.1	19.0	32.3	18.9	32.3	19.0	32.6
4	open	closed	open	open	closed	design	✓	0.5					24.4	36.4	24.6	36.8	24.3	37.1	25.5	38.6	22.6	37.1	23.1	36.6
5	open	closed	closed	closed	closed	design	✓	0.5					29.3	40.8	29.4	40.9	29.0	40.5	29.3	42.3	29.6	41.4	29.3	41.7
6	open	open	closed	closed	open	design		0.5					18.9	32.2	19.0	32.4	18.9	32.2	19.1	32.4	19.1	32.5	19.2	32.8
7	open	closed	open	open	closed	design		1.0	✓				18.9	33.3	19.0	34.2	18.9	34.1	19.1	34.6	19.0	33.5	19.1	33.8
8	open	open	open	open	open	design		0.5		✓			18.9	32.2	19.0	32.4	18.9	32.3	19.0	32.3	18.9	32.4	19.0	32.7
9	open 0.5	open 0.5	open 0.5	open 0.5	open	design	✓	0.5					19.0	32.1	19.2	32.5	19.0	32.2	19.3	33.2	19.1	32.4	19.2	32.7
10	open	open 0.05	open	open	open	design	✓						20.6	33.2	21.3	34.6	20.3	34.6	22.7	36.4	21.0	33.9	21.1	33.5

Table 5.3. Simulation-Summary of findings

5.4.3. Mid Season – Internal Temperature levels

The building was simulated for Days 99-112 (April 09-April 22). The vents were operated according to design and all the external windows were closed.

- **Model 1**

With external Temperature levels ranging from 9.5-20^{0}C, the lowest Temperature in the interior was 18^{0}C, but Temperature could reach uncomfortable levels (Figure 5.16).

- **Model 2**

The external windows were assigned a function, opening when internal temperature was above 23^{0}C.

The Temperature pattern in TAP and North Offices can be seen in the following graph.

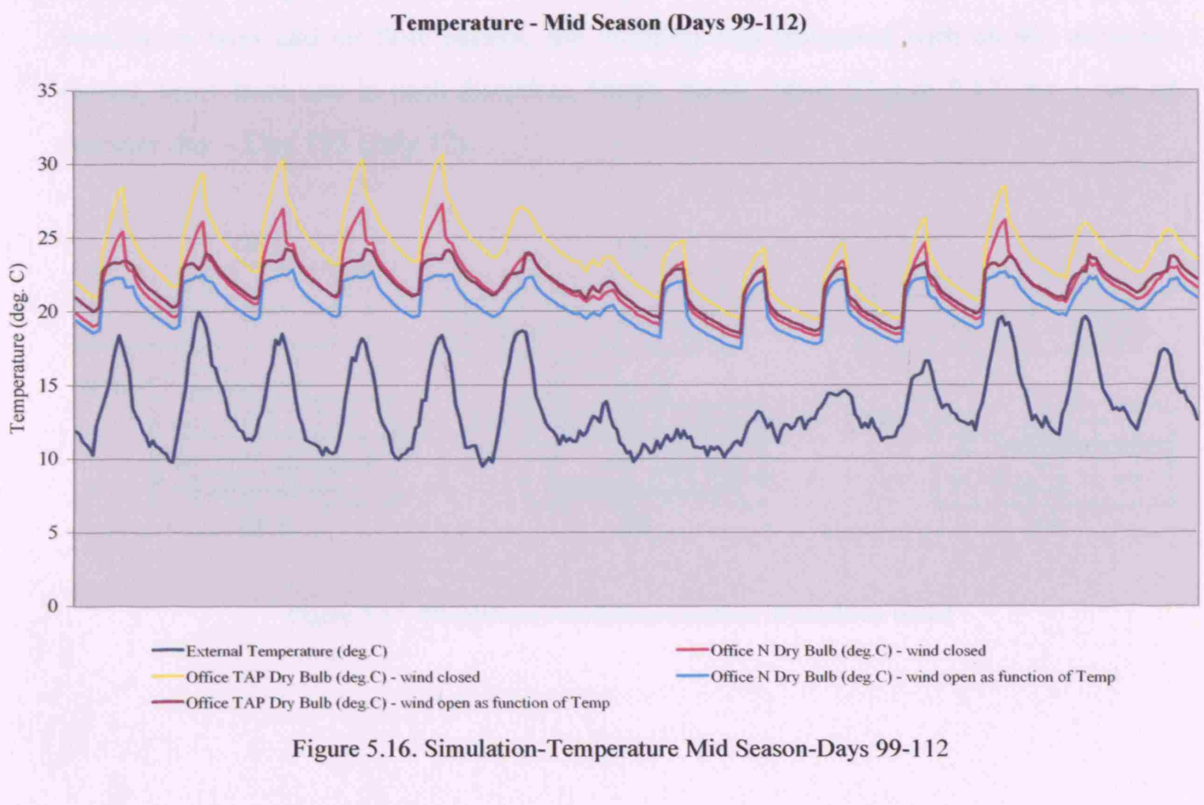


Figure 5.16. Simulation-Temperature Mid Season-Days 99-112

Mid-season-Summary of findings											
				External Temperature range (^{0}C)		Temperature range (^{0}C)					
						N offices		S offices		TAP offices	
Model	internal doors	TAP wall vents	External windows-doors	min	max	min	max	min	max	min	max
1	closed	design	closed	9.5	20.0	18.1	27.6	18.2	29.2	19.0	32.0
2	closed	design	open when internal Temperature >23^{0}C			17.4	23.6	17.5	25.2	18.2	24.7

Table 5.4.Simulation-Mid-season-Summary of findings

5.4.4. Ventilation rates

In order to investigate to what extent blocking the Atrium and Clerestory windows affects ventilation rates and air flow pattern, the building was simulated with all the windows closed, apart from one in each direction, North, South, West (Figure 5.17) for a typical summer day – Day 193 (July 12).

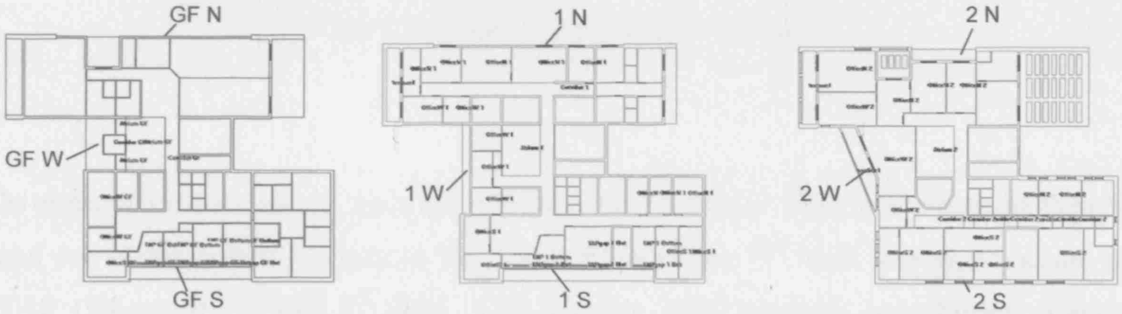


Figure 5.17. Simulation-Ventilation-Location of windows tested

It was simulated with Atrium and Clerestory windows open and closed. The results are illustrated in the following Table 5.5. They do not correspond to actual ventilation rates in the building, as only one window per each direction is open. However, it can be observed that by opening Atrium and Clerestory windows, ventilation rates are approximately doubled. External Temperature levels and wind speed can be seen in Appendix E-3.

	VENTILATION RATES - BUILDING			
	Atr/Clerest open		Atr/Clerest closed	
	Flow in (Kg/s)	Flow out (Kg/s)	Flow in (Kg/s)	Flow out (Kg/s)
GF N	0.355	0.000	0.226	0.000
GF W	0.212	0.000	0.164	0.012
GF VENT lower	0.001	0.003	0.000	0.007
GF TAP External	0.000	0.039	0.000	0.066
GF S	1.250	2.706	0.060	0.961
1 N	1.470	0.000	0.886	0.000
1 W	0.743	0.000	0.449	0.000
1 VENT lower	0.001	0.003	0.000	0.010
1 TAP External	0.000	0.083	0.000	0.170
1 S	0.576	0.393	0.018	1.318
2 N	1.880	0.000	1.152	0.083
2 W	0.116	0.116	0.105	0.105
2 S	0.019	0.499	0.000	1.492
A	0.000	4.784	0.000	0.000
C	0.000	1.038	0.000	0.000
average	**6.621**	**9.664**	**3.061**	**4.223**
increase (%)	46.2	43.7		

Table 5.5.Simulation-Ventilation rates-Building

In terms of air flow pattern, air is draw in from the North and West, while both air flow in and out of the building occurs in the West Office of the 2nd floor. The same occurs in TAP Offices of GF and 1st floor, with external TAP windows contributing slightly compared to the glazed doors.

Ventilation rates with all windows open were investigated for a typical TAP Office of GF (Figure 5.18, Table 5.6).

Figure 5.18. Simulation-Ventilation-Location of TAP Office tested

VENTILATION RATES - TAP OFFICE									
	Model	External windows	TAP system (vents)	Atrium/ Clerestory windows	Infiltration (ach)	air flow rate (Kg/sec)	ach	comparison	% of increase
WINTER Day 38	1	open 0.05	design	closed	0.5	0.08	7.04		
	2	open 0.05	design	open 0.05	0.5	0.09	7.92	models 1-2	12.5
	3	open 0.1	design	closed	0.5	0.16	14.08	models 1-3	100.0
SUMMER Day 193	1	open 0.05	design	closed	0.5	0.08	7.40		
	2	open 0.05	design	open 0.05	0.5	0.10	8.96	models 1-2	21.0
	3	open 0.1	design	closed	0.5	0.18	15.58	models 1-3	110.0

Table 5.6.Simulation-Ventilation rates-TAP Office

Winter: With windows open at 5% of their surfaces air flow rates correspond to 7 ach. A minimum of 6 ach is required for a Police Building [5]. With Atrium and Clerestory windows open, ventilation rates increase by 12.5%, while when opening area is doubled, ventilation rates are doubled as well.

Summer: Atrium and Clerestory windows opening results in a 21% increase in ventilation rates. However, a 5% open area may correspond to 7.4 ach, but internal Temperature is very high, as seen in Chapter 5.4.2.

5.4.5. Annual performance - Heating

The building was simulated for the whole year with heating in order to achieve a thermally comfortable level for the whole year. Taking into account the clothing level of Policemen (APPENDIX E-4) and their activity, the UC Berkeley Thermal Comfort program was used [1] in order to determine the internal Temperature for winter. Although a PMV of 0 was achieved at 19.8^{0}C, at 19^{0}C the PMV was close to 0 (-0.15) which was within the comfortable levels. Thus, a thermostat was applied in the simulation, heating up to 19^{0}C according to the Police Station Schedule. All windows were closed and vents operating according to the design. Infiltration rates were assumed to be 0.5 ach. This corresponds to an annual Heating Load of 14.29 kWh/m^2 (for the Office and common spaces of the building).

Different scenarios were applied and the results are summarized in Table 5.7.

In order to investigate the benefit of operating the TAP system correctly, the model was simulated with vents blocked, that is closed. The figure was slightly lower than the previous (14.2 kWh/m^2), suggesting that good or bad operation of the system made no difference. A higher figure would have been expected. It is believed that modeling in TAS could not simulate this accurately. The building could not be simulated with the correct dimensions of the TAP gap (air space between glazing and absorber), 50mm. The minimum gap that could be achieved was approximately 170mm, which is more than 3 times larger than the initial (Figure 5.19). The size of the air space is believed to reduce the efficiency of the TAP system in the simulation.

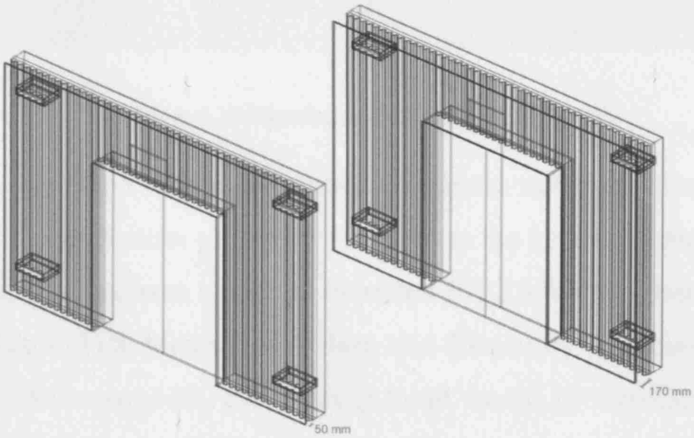


Figure 5.19.Simulation-TAP construction-Building-Model

The Clerestory windows were blocked, as in the constructed building. There was a very small increase in the Heating Load, meaning that their blocking does not decrease significantly Direct Solar Gains.

In all this simulations however, all external windows were closed corresponding to a sealed building. Since the building is ventilated only by cross-ventilation through opening windows, a percentage of the openings area that would have to be open in order to provide an adequate rate of ventilation was calculated.

With external windows and doors open at 5% of their surface, the annual Heating Load of the building (offices and common spaces) is 55.14 kWh/m^2. The Heating Profile for the whole year can be seen in the following graph.

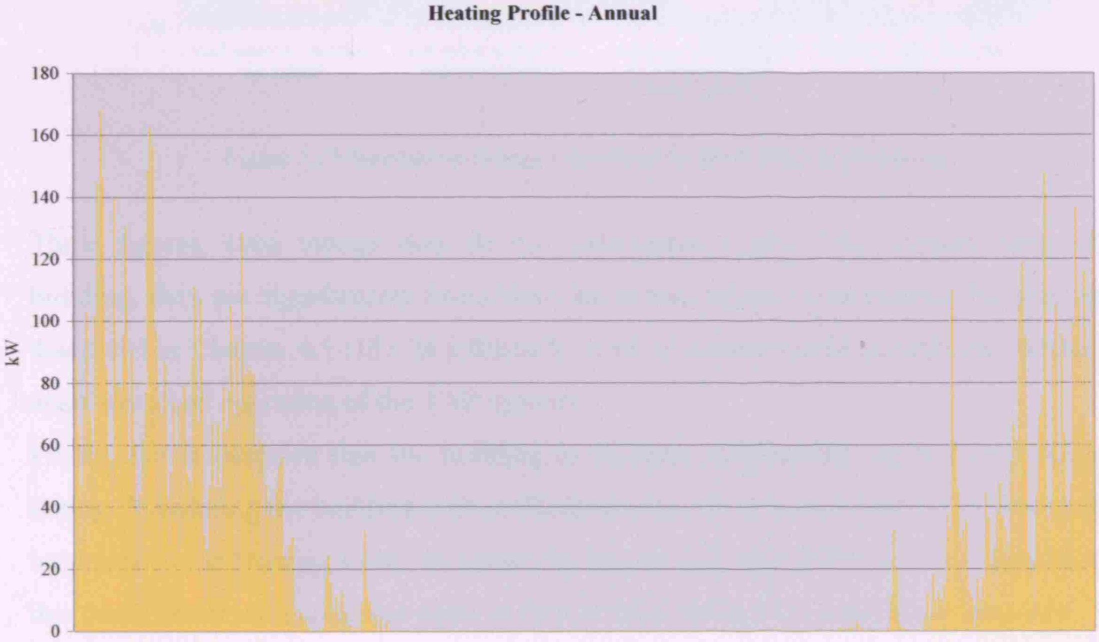


Figure 5.20.Simulation-Annual Heating Profile

The model was simulated with a conventional external wall instead of a TAP wall so as to investigate the contribution of the TAP system to the heating demand of the building. The annual Heating Load was higher as expected (61.2 kWh/m^2), but the difference was not very significant (11% higher). If Atrium and Clerestory windows were open during winter for ventilation purposes, the Heating Load would be significantly higher. There would be a slight decrease (3.9 %) if all the TAP systems of the initial design were constructed.

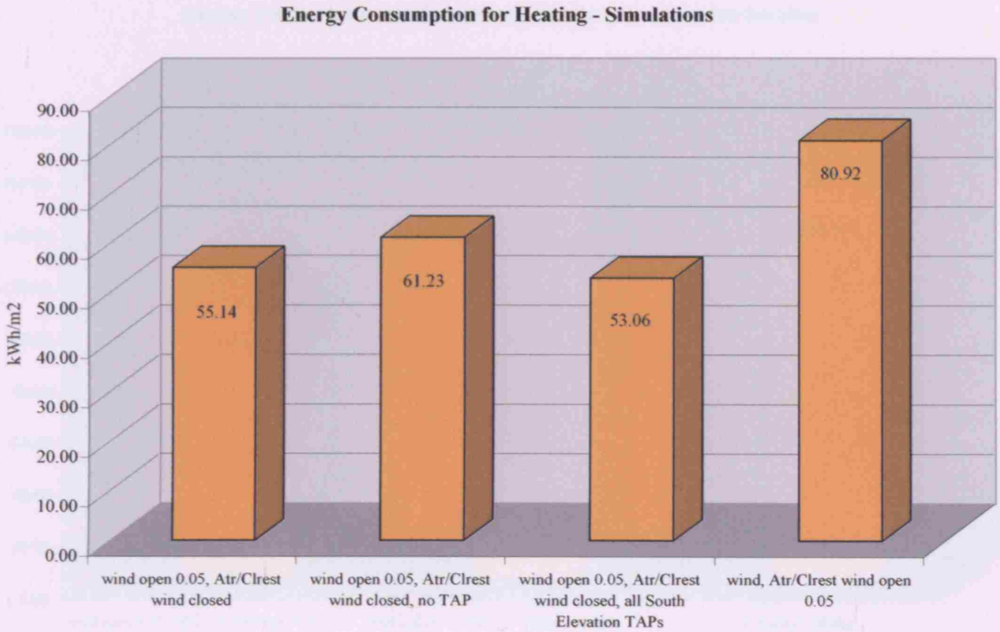


Figure 5.21.Simulation-Energy Consumption for Heating-Simulations

These figures, even though they do not correspond to the Total Heated Area of the building, they are significantly lower than the actual energy consumption for heating, as discussed in Chapter 4.5 (151.38 kWh/m^2). A lot of factors could explain this difference, apart from bad operation of the TAP system.

Firstly, the assumption that the building is air-tight (infiltration rate 0.5 ach) might be wrong. Simulating the building with infiltration rates of 1.0 and 2.0ach result in important increases in the Heating Load, as shown in Figure 5.22 and Table 5.7. In a similar way, this could occur with windows open at 10% of their surface for ventilation purposes.

A very important reason is the internal conditions in the building. The thermostat is likely to have been set to a higher Temperature than it would be required. Assuming that heating up to 22^{0}C was applied and applying different scenarios in terms of infiltration and windows opening, very high figures for Heating Load can occur, similar to the actual consumption (Figure 5.22).

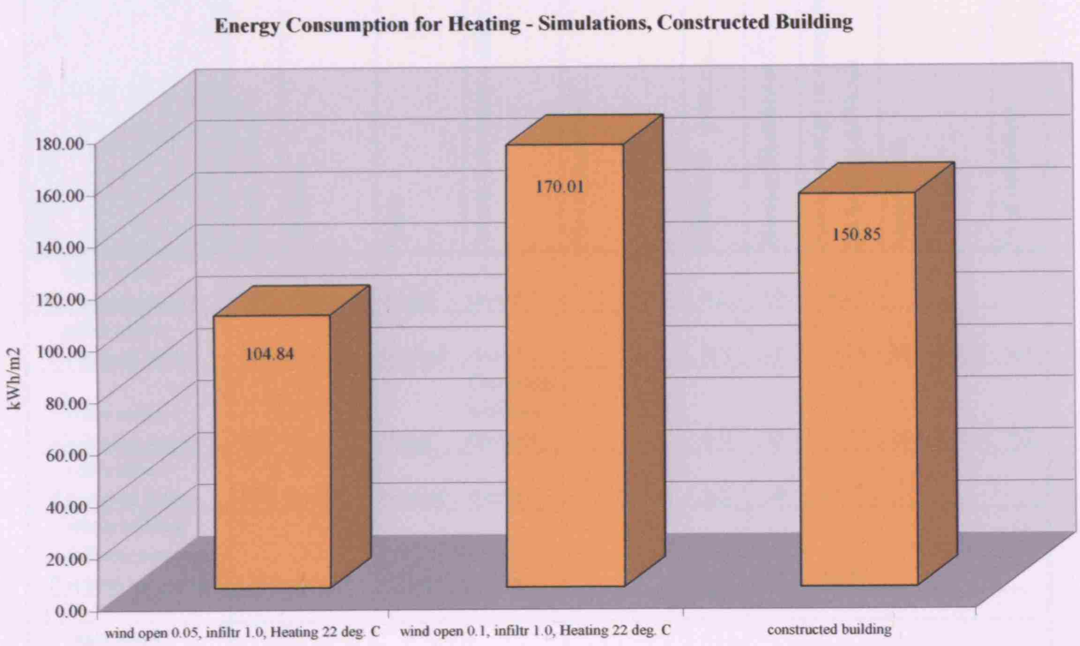


Figure 5.22.Simulation-Energy Consumption for Heating-Simulations, Constructed Building

Model		Heated Area (m^2)	Windows	Vents	Atrium/Clerestory windows	Model alterations	Infiltration (ach)	Heating-Thermostat (^{0}C)	Annual energy consumption for heating (kWh/m^2)	comparison	% of difference
1	office areas - common spaces	897	closed	design	closed		0.5	19	14.29		
2	office areas - common spaces	897	closed	blocked	closed		0.5	19	14.24	Models 1-2	0.4
3	office areas - common spaces	897	closed	design	Clerestory windows blocked		0.5	19	14.33	Models 1-3	0.2
4	office areas - common spaces	897	closed	blocked	closed		0.5	22	25.97		
5	whole building (offices, common spaces and rooms)	1509	closed	design	closed		0.5	19	19.57		
6	office areas - common spaces	897	open 0.05	design	closed		0.5	19	55.14		
7	office areas - common spaces	897	open 0.05	design	open 0.05	conventional external wall instead of	0.5	19	61.23	Models 6-7	11.0
8	office areas - common spaces	897	open 0.05	design	closed	all South Elevation TAPs	0.5	19	53.06	Models 6-8	3.9
9	office areas - common spaces	897	open 0.05	design	open 0.05		0.5	19	80.92	Models 6-8	46.8
10	office areas - common spaces	897	open 0.05	design	closed		1.0	19	69.00		
11	office areas - common spaces	897	open 0.05	blocked	closed		1.0	19	68.84		
12	office areas - common spaces	897	open 0.05	design	closed		2.0	19	95.04		
13	office areas - common spaces	897	open 0.1	design	closed		0.5	19	84.50		
14	office areas - common spaces	897	open 0.1	design	closed		1.0	19	98.72		
15	office areas - common spaces	897	open 0.1	design	closed		2.0	19	125.12		
16	office areas - common spaces	897	open 0.05	blocked	closed		1.0	22	104.84		
17	office areas - common spaces	897	open 1.0	blocked	closed		1.0	22	170.01		
18	constructed	1509							150.85		

Table 5.7.Simulation-Energy Consumption for Heating-Different scenarios

5.5. SUMMARY OF RESULTS – DISCUSSION

The buildings performance during winter was satisfactory. Internal Temperature ranged from 6.1-19.1^{0}C in the building generally and from 7.2-25^{0}C in the TAP Offices, with a minimum difference of 5^{0}C from external Temperature.
The results were not as expected for summer period. The best performance of all the scenarios applied in terms of internal Temperature levels was similar to the external (18.9-32.6^{0}C), having approximately identical fluctuations. A reason for that must be the ineffective application of shading devices in the simulation.
The TAP system was proven to be ineffective for ventilation purposes. The air flow induced by the system is insignificant, as the adjacent external doors of the Tap Offices should be open as well in order to provide higher ventilation rates and the best possible internal Temperature levels. Having the Atrium and Clerestory windows open, as in the initial design, would result in a 50% increase in ventilation rates in the building. However, even in that case (stack effect and not only cross ventilation), internal comfort levels would not be acceptable in summer, in terms of Temperature, suggesting that additional cooling might be required or a different strategy for Passive Cooling.
The TAP system contribution to the heating of the Offices areas (and Common spaces) was 11%. It is believed that the figure is not very high because of reduced performance of the system in simulation, discussed in Chapter 5.4.5 (Figure 5.19). For the same reason there was no conclusion for the effect of the system's operation in energy consumption. Despite that, the buildings performance for the whole year in terms of Heating Load was quite good (55.14 kWh/m^2). This is attributed to Direct Solar Gains, insulation levels, minimum ventilation rates and the TAPs.
Although the figure refers to the Offices area only, comparisons can be made. Besides, the whole building comprises spaces such as rest rooms, which are not usually found in typical Office Buildings. Therefore the figure given can be used as a base for evaluation. It is approximately 70% of the Heating Load (heating, hot water) of a typical Good Practice Naturally ventilated Office, according to ECON 19 [6].Yet, it must be noted that heating demands are different for a building in the UK and for one in Greece. The actual energy consumption for heating was 3 times higher than the figure from simulation. As

discussed, this could be due to thermostat levels, opening adjustments and generally occupants behaviour.

Overall, the building according to simulation, can be characterized as a “Low Energy Consumption” building, as its Heating Load is within 40-80 kWh/m^2 [7].

REFERENCES

[1] Provided in the Environmental Design and Engineering MSc, UCL for coursework and report purposes

[2] Building plans of Police Station of Kilkis, Hellenic Republic, Prefecture of Kilkis, Department of Urban Planning

[3] CIBSE, *Applications Manual AM10: 1997, Natural Ventilation in Non-Domestic Buildings*, The Chartered Institution of Building Services Engineers, London, 1997, p. 16

[4] as [3], p.16

[5] Scottish Home and Health Department, *The Planning of Police Buildings (Scotland) Part 2, Appendices*, Scottish Executive Development Department, 1988, p.55

[6] Best Practice Programme, *Energy Consumption Guide 19: Energy Use In Offices*, Energy Efficiency Office, 2000, p.20

[7] Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.332

(original in Greek:

Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7^{ου} Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

6. CONCLUSIONS

The energy efficient design competition for the new Building of the Police Station of Kilkis was an example of the Government's policy of the past few years to address the issues of sustainability and energy conservation to new Public Buildings.

The bioclimatic design was carried out in a holistic approach, despite the vague requirements of the Brief of the Competition, in terms of energy efficiency. The different features were designed in a way that Passive Solar Gains, Shading, Passive Cooling and provision for Natural light were treated equally. In addition, improvement of microclimate conditions was considered as well.

There were differences between the initial design and the constructed building. The most important were: the construction of only a part of the TAP systems of the South Elevation, the construction of the atrium roof without opening parts and blocking of the clerestory windows.

The building was monitored for 25 days in a late mid-season – early summer period. Temperatures in all the Offices that were monitored fluctuated less than the External Temperature. However, there was no similar pattern in internal Temperatures in relation to external Temperatures, in the different offices that were monitored. Although maximum Temperatures were lower than the external for a certain period, they were generally higher for most of the monitoring period. Comparing internal conditions of two TAP Offices for the same period, results were within the thermal comfort zone, according to the Psychrometric chart, only for the GF Office. All these are related to the occupants behaviour, in terms of external windows opening adjustments. It must be noted that the TAP system was not operated properly in every Office (blocked air flow inlets and outlets by furniture layout).

From a questionnaire survey that was carried out on a typical weekday, it was shown that the majority of people did not know about the PSS systems constructed in the building but they would find it useful to have information about these features. They were satisfied by the internal environmental conditions in the building, giving positive comments, as they rated the general working conditions as good.

The effect of the differences in construction and operation were investigated using computer simulation (TAS software). The building performance was good during winter. Differences between External and Internal Temperature ranged from 5-13^{0}C. The overall good performance is attributed to Direct and Passive Solar Gains, insulation and normal ventilation rates. On the contrary, internal Temperatures for summer period were approximately identical to the external. The effect of shading could not be simulated properly, while the TAP system did not seem to contribute to Passive Cooling or to an increase in ventilation rates.

Having the atrium and clerestory windows open, as in the initial design, was found to increase ventilation rates by 50% (summer). Yet, even in this case (stack effect and cross ventilation), additional cooling seems to be required in order to achieve acceptable internal comfort levels or another strategy for Passive Cooling. It must be noted though, that operating the water feature of the site could improve conditions by providing a form of evaporative cooling.

The energy consumption for heating (annual, heating to 19^{0}C, normal infiltration and ventilation rates) was found as 55.14 kWh/m^2, from the simulation. If TAPs were not constructed, it would be higher by 11%, while if all the external walls (GF abd 1st floor) of the South Elevation were constructed with TAPs, as in the initial design, it would be lower by 4%. The contribution of the TAP system is not very significant. Yet, it is believed that the fact that the system could not be accurately simulated (in terms of construction) as explained in Chapter 5.4.5, might be a reason for poor performance in simulation. For the same reason there were no conclusions concerning the effect of good or bad operation of the TAP system (open-closed vents, blocked air flow paths).

Although the figure for annual energy consumption for heating does not correspond to the whole heated area (Offices and common spaces, not rooms and temporary use spaces), it gives an indication of the building performance.

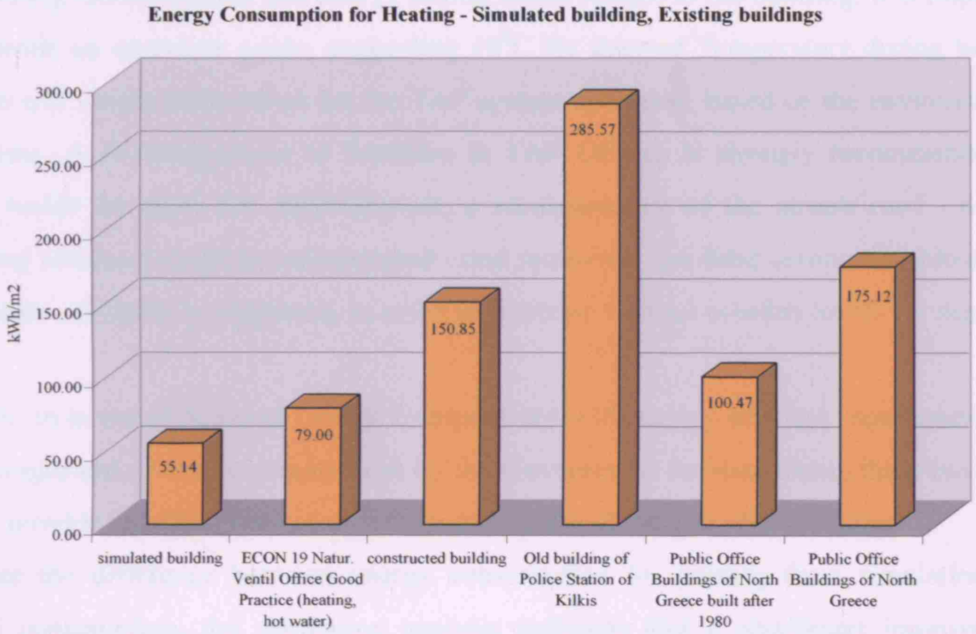


Figure 6.1. Energy Consumption for Heating-Simulated building-Existing buildings

There is a significant difference between the figure from simulation and that from the actual energy consumption. High thermostat Temperature levels or opening adjustments might be the reason for that, as discussed in Chapter 5.4.5. Compared to existing Public Office Buildings of North Greece [1], the actual energy consumption for heating is approximately 85% of the average consumption, but 50% higher than that of recently built buildings. Although the energy consumption for heating is nearly half the amount of the old building of Police Station, it could be improved to a great extent. Of course, it might not reach the figure of a simulation, as many factors affect the energy consumption in reality. Yet, there are indications that it could be reduced.

Further research could be based on monitoring the building during winter. For this purpose, thermostats should be set to 19^{0}C and a re-arrangement of furniture layout would be required in the TAP Offices, so that there would be no obstructions in air flow paths of the TAPs.

If any suggestions could be made to the buildings occupants, since there was no information or any type of operation guide for the building, information about the features and PSS of the building would be helpful, as it could increase awareness concerning environmental and energy saving issues related to the building. It is important to provide an operation guide, suggesting 19^0C for internal Temperature during heating season and simple instructions for the TAP system operation, based on the environmental diagrams. A re-arrangement of furniture in TAP Offices is strongly recommended. If there would be plans for refurbishment, a reconstruction of the atrium roof - so that opening windows could be incorporated - and removing the false ceiling that blocks the clerestory windows is suggested, in order to improve thermal comfort levels for summer-time.

Finally, in terms of National Design Competitions with energy efficient requirements, an encouragement or even a requirement by the Government for monitoring these buildings could provide significant data for performance and indicate possible mistakes.

Despite the difference between energy consumption for heating from simulation and actual consumption, the simulation analysis indicates that a significant improvement could be achieved with proper operation of the building at acceptable thermal comfort levels. In an ideal case, the figure of 55.14 kWh/m^2 for heating would be required, corresponding to significant savings in energy consumption.

REFERENCES

[1] Liveris P., Aravantinos D., Papadopoulos A., Tsakiris N., *Guide of Energy Saving in Public Buildings*, European Commission- Directorate General XVII for Energy, Thessaloniki, 1996, p.19-20
(original in Greek:
Λιβέρης Π. , Αραβαντινός Δ. , Παπαδόπουλος Α. , Τσακίρης Ν. , Οδηγός Εξοικονόμησης Ενέργειας στα Δημόσια Κτίρια, Ευρωπαϊκή Επιτροπή-XVII Γενική Διεύθυνση Ενέργειας, Θεσσαλονίκη, 1996)

SOURCES OF ILLUSTRATIONS

Figures

Figure 6.1. data about Existing buildings based on, Liveris P., Aravantinos D., Papadopoulos A., Tsakiris N., *Guide of Energy Saving in Public Buildings*, European Commission- Directorate General XVII for Energy, Thessaloniki, 1996, p.20, Table 4
(original in Greek:
Λιβέρης Π. , Αραβαντινός Δ. , Παπαδόπουλος Α. , Τσακίρης Ν. , Οδηγός Εξοικονόμησης Ενέργειας στα Δημόσια Κτίρια, Ευρωπαϊκή Επιτροπή-XVII Γενική Διεύθυνση Ενέργειας, Θεσσαλονίκη, 1996)

BIBLIOGRAPHY

Achard P., Gicquel R. (editors), *European passive solar handbook : basic principles and concepts for passive solar architecture*, Preliminary edition, Commission of the European Communities, Directorate General XII for Science, Research and Development, Brussels, 1986

Anderson B., *Solar Energy: Fundamentals in Building Design*, McGraw-Hill, New York, 1977

Best Practice Programme, *Energy Consumption Guide 19: Energy Use In Offices*, Energy Efficiency Office, 2000

CIBSE, Applications Manual AM10: 1997, Natural Ventilation in Non-Domestic Buildings, The Chartered Institution of Building Services Engineers, London, 1997

Crysomallidou Niobe, *Research of the efficiency of specific strategies for the improvement of natural cooling and lighting of office buildings*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.317-324
(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση της Αποδοτικότητας Συγκεκριμένων Προτάσεων για τη Βελτίωση του Φυσικού Δροσισμού και Φωτισμού Κτιρίων Γραφείων*, Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνκού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

Chrysomallidou Niobe, *Research and evaluation of the potential of application of energy saving measures for passive heating of a new public building*, in Institute of Solar Technology, Tsiligiridis G., Kaouris I. (editors), *Proceedings of 7th National Conference for Alternative Forms of Energy, Patra 6-8 November 2002, Volume A*, Institute of Solar Technology, University of Patra, Department of Mechanical and Aeronautical Engineers, Patra, 2002, p.325-332

(original in Greek:
Χρυσομαλλίδου Νιόβη, *Διερεύνηση & Αξιολόγηση της Δυνατότητας Εφαρμογής Μέτρων Εξοικονόμησης Ενέργειας για την Παθητική Θέρμανση ενός Νέου Κτιρίου Του Δημοσίου*, στο: Ινστιτούτο Ηλιακής Τεχνικής, Τσιλιγκιρίδης Γ., Καούρης Ι. (επιμέλεια), *Πρακτικά 7ου Εθνικού Συνεδρίου Για Τις Ήπιες Μορφές Ενέργειας, Πάτρα 6-8 Νοεμβρίου 2002*, Ινστιτούτο Ηλιακής Τεχνικής, Πανεπιστήμιο Πατρών, Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών, Πάτρα, 2002)

Department For Education, Architects and Building Division, Building Bulletin 79: *Passive Solar Schools: A design guide*, HMSO, London, 1994

Goulding J., Lewis O., Steemers T. (editors), *Energy Conscious Design-A Primer for Architects,* European Commission- Directorate General XII for Science, Research and Development, London, 1992
(original in Greek:
Goulding J., Lewis O., Steemers T. (επιμ.), Ενεργειακός Σχεδιασμός. Εισαγωγή για Αρχιτέκτονες, Μαλλιάρης, Θεσσαλονίκη, 1994)

Hastings R., Mærck O. (editors), *Solar Air Systems: a Design Handbook*, James & James, London, 2000

Hellenic Public Real Estate Corporation, *Competition Brief: Design and Construction of Police Station in Kilkis, 1. Public Proclamation of Open Competition*, Hellenic Public Real Estate Corporation, Athens, 1999
(original in Greek:
Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Τεύχη Δημοπράτησης, 1. Διακήρυξη Ανοιχτής Δημοπρασίας*, Κτηματική Εταιρία του Δημοσίου, Αθήνα, 1999)

Hellenic Public Real Estate Corporation, *Competition Brief: Design and Construction of Police Station in Kilkis, 4. Description-Building Requirements*, Hellenic Public Real Estate Corporation, Athens, 1999
(original in Greek:
Κτηματική Εταιρία του Δημοσίου, Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς,Τεύχη Δημοπράτησης, 4. Περγραφή Αντικειμένου, Κτιριολογικό Πρόγραμμα, Κτηματική Εταιρία του Δημοσίου, Αθήνα, 1999)

Hellenic Public Real Estate Corporation, *Design and Construction of Police Station in Kilkis, Design Report of Electrical/Mechanical Services-Technical Description* , Hellenic Public Real Estate Corporation, Thessaloniki, 2000
(original in Greek:
Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Μελέτη Εφαρμογής Η/Μ Εγκαταστάσεων, Τεχνική Περιγραφή*, Κτηματική Εταιρία του Δημοσίου, Θεσσαλονίκη, 2000)

Hellenic Public Real Estate Corporation, *Design and Construction of Police Station in Kilkis, Design Report of Electrical/Mechanical Services-Technical Design* , Hellenic Public Real Estate Corporation, Thessaloniki, 2000
(original in Greek:
Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Μελέτη Εφαρμογής Η/Μ Εγκαταστάσεων, Τεχνική Μελέτη*, Κτηματική Εταιρία του Δημοσίου, Θεσσαλονίκη, 2000)

Hellenic Public Real Estate Corporation, *Design and Construction of Police Station in Kilkis, Design Report of Electrical/Mechanical Services-Technical Specifications* , Hellenic Public Real Estate Corporation, Thessaloniki, 2000
(original in Greek:
Κτηματική Εταιρία του Δημοσίου, *Μελέτη-Κατασκευή Κτιρίου Αστυνομικής Διεύθυνσης Κιλκίς στο Κιλκίς, Μελέτη Εφαρμογής Η/Μ Εγκαταστάσεων, Τεχνικές Προδιαγραφές*, Κτηματική Εταιρία του Δημοσίου, Θεσσαλονίκη, 2000)

Lebens R., *Passive Solar Heating Design*, Applied Science Publishers, London, 1981

Liveris P., Aravantinos D., Papadopoulos A., Tsakiris N., *Guide of Energy Saving in Public Buildings*, European Commission- Directorate General XVII for Energy, Thessaloniki, 1996
(original in Greek:
Λιβέρης Πάνος, Αραβαντινός Δημήτρης, Παπαδόπουλος Άγις, Τσακίρης Νίκος, Οδηγός Εξοικονόμησης Ενέργειας στα Δημόσια Κτίρια, Ευρωπαϊκή Επιτροπή XVII Γενική Διεύθυνση Ενέργειας, Θεσσαλονίκη, 1996)

Scottish Home and Health Department, *The Planning of Police Buildings (Scotland) Part 2, Appendices*, Scottish Executive Development Department, 1988

Steven Winter Associates, edited by **Crosbie M. J.**, *The Passive Solar Design and Construction Handbook*, John Wiley & Sons, Inc., New York, Chichester, 1998

Tsiligiridis G., *Renewable Sources of Energy, Notes*, Aristotle University of Thessaloniki Publications, Thessaloniki, 2001

INTERNET SOURCES

http://www.expedia.com/pub/agent.dll?qscr=over&rfrr=-357 [August 2005]

http://www.lonelyplanet.com/worldguide/destinations/europe/greece [August 2005]

http://www.minerv.gr/4/47/471/g47100.html [August, 2005]

http://www.minerv.gr./1/13/132/13201g1320104.html [August, 2005]

http://www.minenv.gr./1/13/132/13201g1320104.html [August, 2005]

APPENDICES

APPENDIX A. DESIGN GROUP OF BUILDING

Architectural Design:

Papas B., Architect

Design Team 406, Architects

Balta M., Architect (Assistant)

Structural Design:

Bakoulis M., Civil Engineer

Electrical/Mechanical Design:

Kaltsogiannis E., Electrical-Mechanical Engineer

Bioclimatic Design:

Chrysomallidou N., Professor, Aristotle University of Thessaloniki, Greece, Department of Civil Engineering

APPENDIX B. QUESTIONNAIRE

Questionnaire

1. Please state your gender

Male	Female

2. Please mark how warm or cold you are right now

Hot	Warm	Slightly warm	Neutral	Slightly cool	Cool	Cold
3	2	1	0	-1	-2	-3

3. Please rate the quality of lighting in this office, (is it easy to see to write?)

Too bright	Bright	OK	Dim	Too dim
2	1	0	-1	-2

4. Please rate the GENERAL quality of lighting in the whole building

Too bright	Bright	OK	Dim	Too dim
2	1	0	-1	-2

5. Please rate the air quality in this office

Very Good	Good	OK	Stuffy	Very stuffy
2	1	0	-1	-2

6. Please rate the GENERAL air quality in the building

Very Good	Good	OK	Stuffy	Very stuffy
2	1	0	-1	-2

7. Please rate the air movement in this office

Draughty	Slightly draughty	Just right	Still	Very still
2	1	0	-1	-2

8. Please rate the GENERAL air movement in the building

Draughty	Slightly draughty	Just right	Still	Very still

9. How many times a day do you typically adjust the opening of the nearest window to you?

Never	Once	Twice	More than twice

10. Please mark where you are seated on the back, on the relevant floor > > > > > > **> > > > > > > > >**

11. Did you know that there are systems in the building (panels on the south wall of Ground and 1st floor) which are constructed in order to save energy?

Yes	No

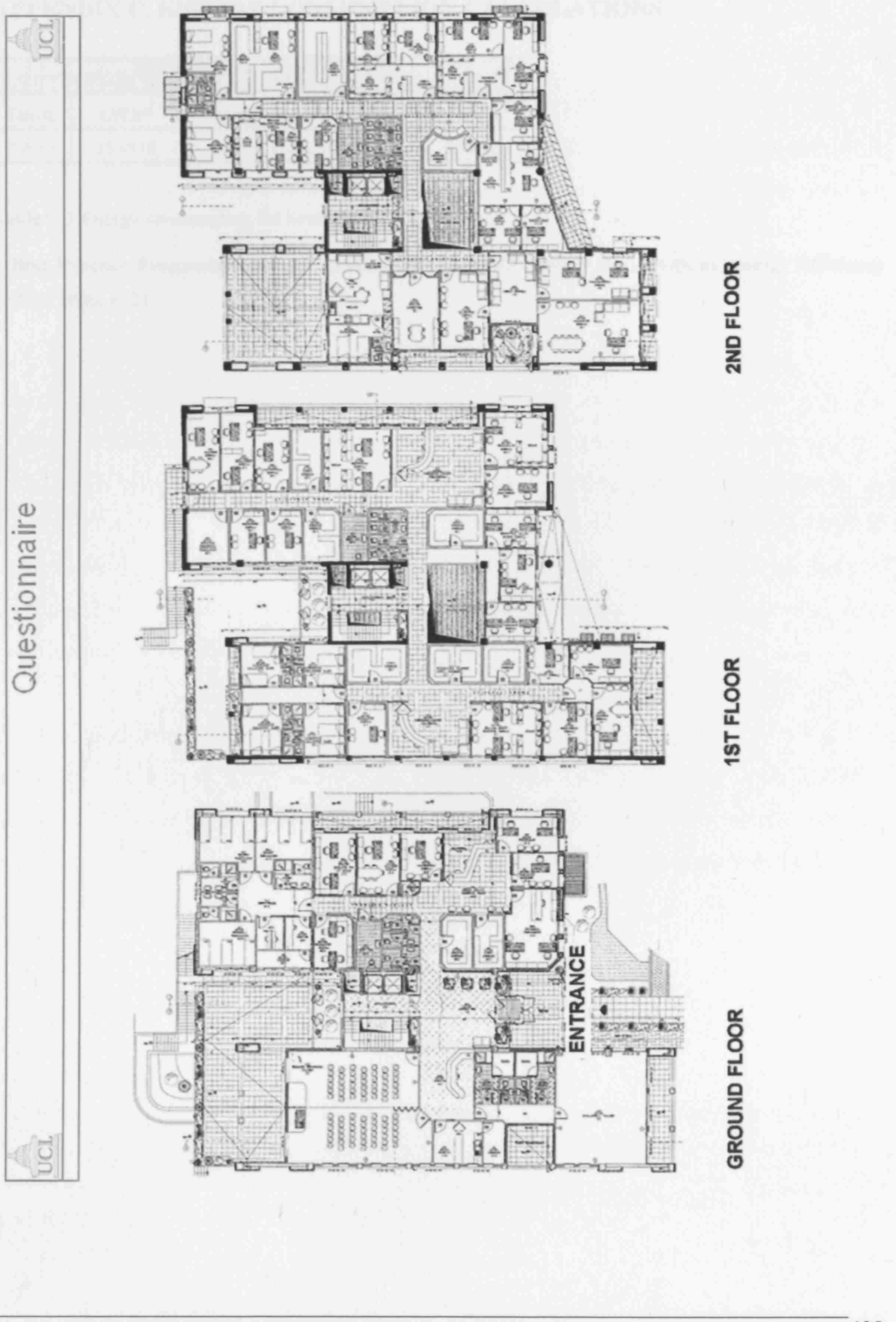
12. Would you find it useful to have information about the function of such systems and how to operate them?

Yes	Neutral	No

13. OVERALL how do you rate the conditions in this building for working?

Very good	Good	Neutral	Bad	Very bad
2	1	0	-1	-2

14. Please make any general comments about the environmental conditions in this building, particularly related to temperature and humidity.


Questionnaire
UCL
2ND FLOOR
1ST FLOOR
GROUND FLOOR
ENTRANCE

APPENDIX C. ENEGRY CONSUMPTION CALCULATIONS

3 months:10250 lt		23916 lt/year	
Oil-lt	**kWh***	**Treated floor area (m^2)**	**kWh/m^2**
23916	253510	1680.54	**150.85**

Table C.1.Energy consumption for heating calculations

* **Best Practice Programme**, *Energy Consumption Guide 19: Energy Use In Offices*, Energy Efficiency Office, 2000, p. 21

APPENDIX D. PROFILE OF BUILDINGS OF CENTRAL MACEDONIA, GREECE

A. Buildings constructed between the end of 19th Century and 1950 (Old) [1]

Their architecture is characteristic, construction is of thick elements, there are small openings and where there is a central heating system, it was installed later. They have the highest energy consumption (207kWh/m^2 annually) but the thermal comfort levels are generally acceptable to satisfactory, particularly in summer.

B. Buildings constructed between 1950 - 1980 (New) [2]

These types of buildings are the majority of buildings in Greek cities, not only the majority of Public Office buildings. Their structural system is of reinforced concrete, they have large openings and no insulation. They have central heating systems but no automatic controls. Most of them were not designed as Office buildings and in consequence changes in the interior have been made. They have high energy consumption (185 kWh/m^2 annually) and in fact medium levels of thermal comfort, both in winter and in summer.

C. Buildings constructed after 1980 (Recent) [3]

They have the best performance, yet represent the minority of the public Office Buildings. Insulation and double glazing is used as well as new building services systems. The energy consumption is satisfactory (139 kWh/m^2 annually) while thermal comfort levels are satisfactory to very good.

1. Liveris P., Aravantinos D., Papadopoulos A., Tsakiris N., *Guide of Energy Saving in Public Buildings*, European Commission- Directorate General XVII for Energy, Thessaloniki, 1996, p.19
(original in Greek:
Λιβέρης Πάνος, Αραβαντινός Δημήτρης, Παπαδόπουλος Άγις, Τσακίρης Νίκος, Οδηγός Εξοικονόμησης Ενέργειας στα Δημόσια Κτίρια, Ευρωπαϊκή Επιτροπή-XVII Γενική Διεύθυνση Ενέργειας, Θεσσαλονίκη, 1996)
2. as 1, p.19
3. as 1, p.19

APPENDIX E. TAS

1. CONSTRUCTIONS

Name: Door Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.600	0.600	0.900	0.900	1.400	1.769

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1wood\1	100.0	0.140	0.000	11.520	500.000	1760.000	SOFTWOOD 1 *3

Name: External25 Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.400	0.400	0.900	0.900	0.416	9.436

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1brick\1	80.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
3	am1ins\15	50.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
4	am1brick\1	80.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
5	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4

Name: ExternalBrick Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.725	0.400	0.930	0.900	0.402	12.178

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1brick\1	90.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
3	am1ins\15	50.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
4	am1brick\1	90.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
5	am1cav\7	100.0	0.000	0.960	1.000	0.000	0.000	100MM AIR (HORIZONTAL F...
6	am1brick\10	100.0	0.810	0.000	8.000	1760.000	920.000	BRICK COMMON DRY 0% m...

Name: ExternalBrickConcr Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.725	0.400	0.930	0.900	0.401	30.618

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1conc\1	230.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1ins\15	50.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
4	am1cav\7	100.0	0.000	0.960	1.000	0.000	0.000	100MM AIR (HORIZONTAL F...
5	am1brick\10	100.0	0.810	0.000	8.000	1760.000	920.000	BRICK COMMON DRY 0% m...

Name: ExternalConcrete Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.400	0.400	0.900	0.900	0.408	32.012

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1conc\1	240.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1ins\15	50.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
4	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4

Name: floor Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.650	0.700	0.900	0.900	11.113	0.000

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1tile\2	30.0	0.850	0.000	52.000	1900.000	837.000	CLAY,RED/BROW...
2	am1concd\9	70.0	1.280	0.000	34.000	2100.000	1000.000	CONCRETE SCREE...

Name: Frame Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.500	0.500	0.216	0.216	816.000	0.000

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1metal\1	250.0	204.000	0.000	99999.0...	2700.000	896.000	ALUMINIUM *3

Name: Ground Floor Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.400	0.650	0.900	0.900	0.446	5.932

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1concd\1	170.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
2	am1ins\15	50.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDE...
3	am1plast\1	30.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER ...

Name: Internal20 Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.400	0.400	0.900	0.900	0.294	5.848

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	30.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1sheet\1	140.0	0.053	0.000	3.840	240.000	1400.000	FIBRE BOARD 1 *1
3	am1plast\1	30.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4

Name: Internal Concrete Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.400	0.400	0.900	0.900	1.337	14.361

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1concd\1	210.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4

Name: InternalWall Description:

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.400	0.400	0.900	0.900	1.688	3.183

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1brick\1	60.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
3	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4

Name PaneExternal Description

Solar Transmittance	External Solar Absorptance		Internal Solar Absorptance		Light Transmittance	Emissivity		Conductance (W/m2 C)	Time Constant (hours)	External Blind	Internal Blind
	ext. surf.	int. surf.	int. surf.	ext. surf.		External	Internal				
0.811	0.158	0.118	0.158	0.118	0.762	0.845	0.845	5.458	0.000	NO	NO

Layer	M-Code	Widt...	Solar...	Ext S...	Int S...	Ext E...	Int E...	Cond...	Conv...	Vapo...	Description
Inside	am1pilk\2	6.0	0.780	0.070	0.070	0.845	0.845	1.000	0.000	9999...	6MM CLEAR FLOAT
2	am1cav\2	12.0	0.000	0.000	0.000	0.000	0.000	0.000	2.080	1.000	12MM AIR (HORIZO...
3	am1pilk\2	6.0	0.780	0.070	0.070	0.845	0.845	1.000	0.000	9999...	6MM CLEAR FLOAT

Name PaneInternal Description

Solar Transmittance	External Solar Absorptance		Internal Solar Absorptance		Light Transmittance	Emissivity		Conductance (W/m2 C)	Time Constant (hours)	External Blind	Internal Blind
	ext. surf.	int. surf.	int. surf.	ext. surf.		External	Internal				
0.700	0.115	0.115	0.115	0.115	0.840	0.845	0.845	100.000	0.000	NO	NO

Layer	M-Code	Widt...	Solar...	Ext S...	Int S...	Ext E...	Int E...	Cond...	Conv...	Vapo...	Description
Inside	am1pilk\3	10.0	0.700	0.070	0.070	0.845	0.845	1.000	0.000	9999...	10MM CLEAR FLOAT

Name roof Description

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.650	0.400	0.900	0.900	0.325	60.580

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	30.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1concd\1	220.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1concd\9	80.0	1.280	0.000	34.000	2100.000	1000.000	CONCRETE SCREED *3
4	am1ins\15	70.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
5	am1tile\3	50.0	1.100	0.000	34.000	2100.000	837.000	CONCRETE, UNCOLOURED...

Name roof Description

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.650	0.400	0.900	0.900	0.325	60.580

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	30.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1concd\1	220.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1concd\9	80.0	1.280	0.000	34.000	2100.000	1000.000	CONCRETE SCREED *3
4	am1ins\15	70.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
5	am1tile\3	50.0	1.100	0.000	34.000	2100.000	837.000	CONCRETE, UNCOLOURED...

Name TAP Description

Solar Transmittance	External Solar Absorptance		Internal Solar Absorptance		Light Transmittance	Emissivity		Conductance (W/m2 C)	Time Constant (hours)	External Blind	Internal Blind
	ext. surf.	int. surf.	int. surf.	ext. surf.		External	Internal				
0.611	0.158	0.118	0.158	0.118	0.762	0.845	0.845	5.458	0.000	NO	NO

Layer	M-Code	Widt...	Solar...	Ext S...	Int S...	Ext E...	Int E...	Cond...	Conv...	Vapo...	Description
Inside	am1pilk\2	6.0	0.780	0.070	0.070	0.845	0.845	1.000	0.000	9999...	6MM CLEAR FLOAT
2	am1cav\2	12.0	0.000	0.000	0.000	0.000	0.000	0.000	2.080	1.000	12MM AIR (HORIZO...
3	am1pilk\2	6.0	0.780	0.070	0.070	0.845	0.845	1.000	0.000	9999...	6MM CLEAR FLOAT

Name TAP BrickWall Description

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.500	0.400	0.216	0.900	0.385	30.045

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1...
2	am1brick\1	255.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
3	am1ins\15	50.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED...
4	am1cav\2	12.0	0.000	2.080	1.000	0.000	0.000	12MM AIR (HORIZONTAL F...
5	am1metal\1	2.0	204.000	0.000	99999.0...	2700.000	896.000	ALUMINIUM *3

Constructions for model with increased insulation levels

Name: ExternalConcrete Description:

Solar Absorptance ext. surf.	Solar Absorptance int. surf.	Emissivity External	Emissivity Internal	Conductance (W/m2 C)	Time Constant (hours)
0.400	0.400	0.900	0.900	0.243	35.315

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER ...
2	am1concd\1	240.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1ins\15	100.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDE...
4	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER ...

Name: External25 Description:

Solar Absorptance ext. surf.	Solar Absorptance int. surf.	Emissivity External	Emissivity Internal	Conductance (W/m2 C)	Time Constant (hours)
0.400	0.400	0.900	0.900	0.246	10.033

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1brick\1	80.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
3	am1ins\15	100.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
4	am1brick\1	80.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
5	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4

Name: ExternalBrick Description:

Solar Absorptance ext. surf.	Solar Absorptance int. surf.	Emissivity External	Emissivity Internal	Conductance (W/m2 C)	Time Constant (hours)
0.725	0.400	0.930	0.900	0.241	12.946

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1brick\1	90.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
3	am1ins\15	100.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
4	am1brick\1	90.0	0.700	0.000	8.000	1700.000	800.000	BRICKWORK *4
5	am1cav\7	100.0	0.000	0.960	1.000	0.000	0.000	100MM AIR (HORIZONTAL F...
6	am1brick\10	100.0	0.810	0.000	8.000	1760.000	920.000	BRICK COMMON DRY 0% m...

Name: ExternalBrickConcr Description:

Solar Absorptance ext. surf.	Solar Absorptance int. surf.	Emissivity External	Emissivity Internal	Conductance (W/m2 C)	Time Constant (hours)
0.725	0.400	0.930	0.900	0.240	33.619

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1concd\1	230.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1ins\15	100.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
4	am1cav\7	100.0	0.000	0.960	1.000	0.000	0.000	100MM AIR (HORIZONTAL F...
5	am1brick\10	100.0	0.810	0.000	8.000	1760.000	920.000	BRICK COMMON DRY 0% m...

Name: Ground Floor Description:

Solar Absorptance ext. surf.	Solar Absorptance int. surf.	Emissivity External	Emissivity Internal	Conductance (W/m2 C)	Time Constant (hours)
0.400	0.650	0.900	0.900	0.256	6.354

Layer	M-Code	Width (...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1concd\1	170.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
2	am1ins\15	100.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
3	am1plast\1	30.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4

Opaque Construction	Name	roof	Description	

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.650	0.400	0.900	0.900	0.185	67.967

Layer	M-Code	Width [...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	30.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1concd\1	220.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1concd\9	80.0	1.280	0.000	34.000	2100.000	1000.000	CONCRETE SCREED *3
4	am1ins\15	140.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
5	am1tile\3	50.0	1.100	0.000	34.000	2100.000	837.000	CONCRETE, UNCOLOURED...

Opaque Construction	Name	RoofClerest	Description	

Solar Absorptance		Emissivity		Conductance (W/m2 C)	Time Constant (hours)
ext. surf.	int. surf.	External	Internal		
0.400	0.400	0.900	0.900	0.190	12.382

Layer	M-Code	Width [...	Conduc...	Convec...	Vapour ...	Density	Specific...	Description
Inside	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4
2	am1concd\1	90.0	0.870	0.000	14.800	1800.000	920.000	CONCRETE 3% m.c. 8 *3
3	am1ins\15	140.0	0.030	0.000	59.000	140.000	1380.000	POLYSTRENE, EXPANDED *2
4	am1plast\1	20.0	0.079	0.000	11.000	400.000	837.000	LIGHTWEIGHT PLASTER 1 *4

Shading Devices

Feature Shade

Name		Overhang100-1-S
Description		
Surface	Height (m)	1.800
	Width (m)	1.000
Left Fin	Depth (m)	0.000
	Offset (m)	0.000
	Transmittance	0.000
Right Fin	Depth (m)	0.000
	Offset (m)	0.000
	Tranmittance	0.000
Overhang	Depth (m)	0.800
	Offset (m)	0.000
	Transmittance	0.100

Weekday
Saturday
Sunday

Gain	Units	Value	Factor	Setback Value	Schedule
Proportion	0-1	1.00	1.00	0.00	

Feature Shade

Name		overhang100-G-W
Description		
Surface	Height (m)	1.300
	Width (m)	1.000
Left Fin	Depth (m)	0.000
	Offset (m)	0.000
	Transmittance	0.000
Right Fin	Depth (m)	0.000
	Offset (m)	0.000
	Tranmittance	0.000
Overhang	Depth (m)	0.800
	Offset (m)	0.000
	Transmittance	0.100

Weekday
Saturday
Sunday

Gain	Units	Value	Factor	Setback Value	Schedule
Proportion	0-1	1.00	1.00	0.00	

Feature Shade

Name		Wind-130_G-E
Description		
Surface	Height (m)	1.300
	Width (m)	1.300
Left Fin	Depth (m)	0.000
	Offset (m)	0.000
	Transmittance	0.000
Right Fin	Depth (m)	0.000
	Offset (m)	0.000
	Tranmittance	0.000
Overhang	Depth (m)	0.800
	Offset (m)	0.000
	Transmittance	0.100

Weekday
Saturday
Sunday

Gain	Units	Value	Factor	Setback Value	Schedule
Proportion	0-1	1.00	1.00	0.00	

Feature Shade

Name		Overhang250
Description		
Surface	Height (m)	0.300
	Width (m)	2.500
Left Fin	Depth (m)	0.000
	Offset (m)	0.000
	Transmittance	0.000
Right Fin	Depth (m)	0.000
	Offset (m)	0.000
	Tranmittance	0.000
Overhang	Depth (m)	0.800
	Offset (m)	0.000
	Transmittance	0.100

Weekday
Saturday
Sunday

Gain	Units	Value	Factor	Setback Value	Schedule
Proportion	0-1	1.00	1.00	0.00	

2. INTERNAL GAINS - CALCULATIONS

Internal Gains-Occupancy					
Offices-Common spaces-weekday					
Occupancy Gains	**W/person**	**n. of people**	**Gains**	**Area (m^2)**	**W/m^2**
Sensible*	93	64	5952	1020.74	5.83
Latent*	37	64	2368	1020.74	2.32
Offices-Common spaces-weekend					
Occupancy Gains	**W/person**	**n. of people**	**Gains**	**Area (m^2)**	**W/m^2**
Sensible*	93	2	186	1020.74	0.18
Latent*	37	2	74	1020.74	0.07

Table E.2.1. Internal Gains – Occupancy

* CIBSE, *Guide A, Environmental Design*, The Chartered Institute of Building Services Engineers, London, 1999, p. 6-2

3. VENTILATION RATES

	WINTER		SUMMER	
Hour	**wind speed (m/s)**	**External Temperature (deg. C)**	**wind speed (m/s)**	**External Temperature (deg. C)**
8	2.5	3.8	0.7	24.9
9	3.2	4.8	1.1	26.4
10	3.2	5.3	2.2	27.9
11	1.5	5.3	2.8	28.2
12	1.4	5.7	4.2	29.5
13	1.3	6.3	3.5	30.4
14	2.5	7.4	2.8	30.3
15	1.9	7.3	4.4	30.8
16	2.1	7.8	3.5	30.1

Table E.3.1. Simulation - Wind speed and External Temperature for ventilation simulations

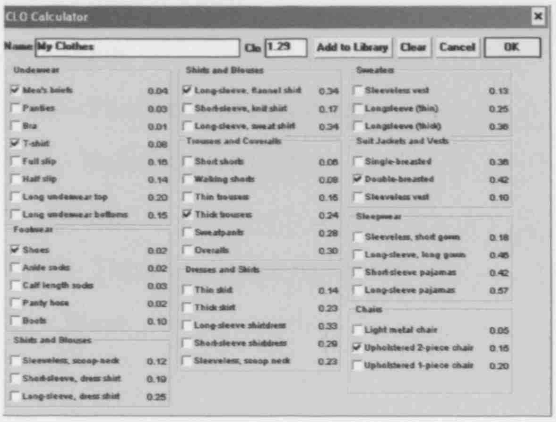
VENTILATION RATES - TAP OFFICE													
	Model	**External windows**	**TAP system (vents)**	**Atrium/ Clerestory windows**	**Infiltration (ach)**	**air flow rate (Kg/sec)**	**d air (Kg/m3)**	**air flow rate (m3/sec)**	**air flow rate (m3/h)**	**Office Volume (m3)**	**ach**	**comparison**	**% of increase**
WINTER Day 38	**1**	open 0.05	design	closed	0.5	0.08	1.229	0.07	234.34	33.288	**7.04**		
	2	open 0.05	design	open 0.05	0.5	0.09	1.229	0.07	263.63	33.288	**7.92**	models 1-2	12.5
	3	open 0.1	design	closed	0.5	0.16	1.229	0.13	468.67	33.288	**14.08**	models 1-3	100.0
SUMMER Day 193	**1**	open 0.05	design	closed	0.5	0.08	1.229	0.07	246.48	33.288	**7.40**		
	2	open 0.05	design	open 0.05	0.5	0.10	1.229	0.08	298.14	33.288	**8.96**	models 1-2	21.0
	3	open 0.1	design	closed	0.5	0.18	1.229	0.14	518.54	33.288	**15.58**	models 1-3	110.0

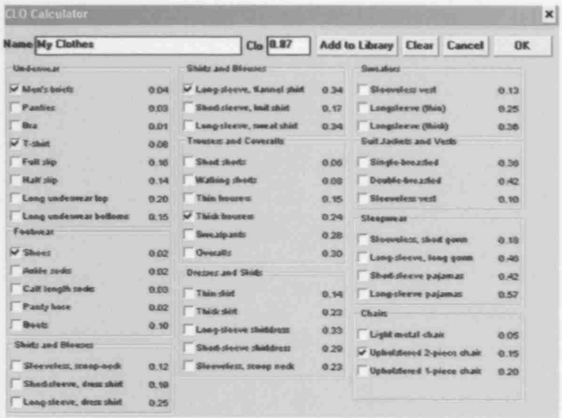
Table E.3.2. Simulation – Ventilation Rates – TAP Office

4. CLOTHING LEVELS - PMV

From UC Berkeley Thermal Comfort Programme (provided for the module E02 of the Environmental Design and Engineering Course, UCL)

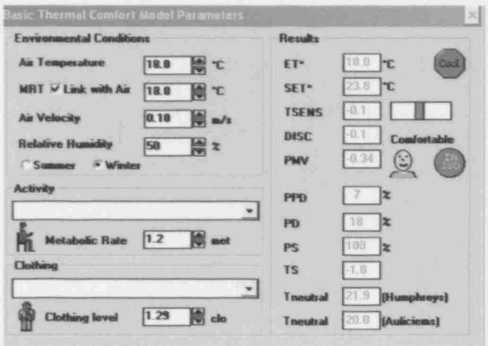
Winter and Summer, respectively:

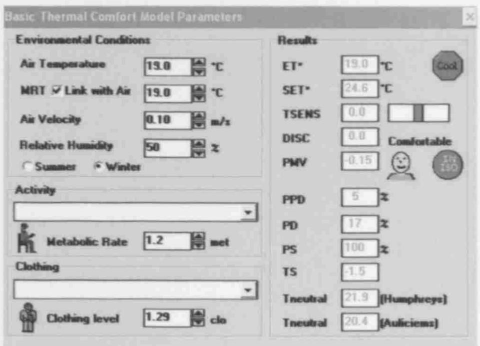


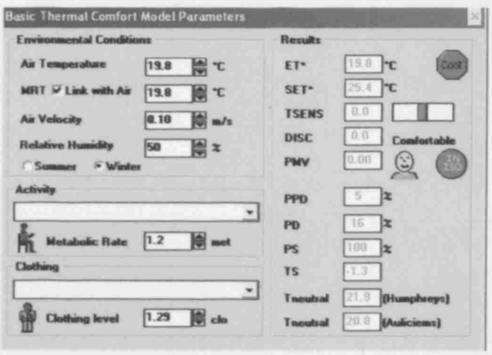


Figures E.4.1, E.4.2, Simulation – Clo values for winter and summer

PMV scale







Figures E.4.3, E.4.4, E.4.5, Simulation – PMV scale for temperatures 18^{0}C, 19^{0}C, 19.8^{0}C

APPENDIX F. ABBREVIATIONS

A - Atrium

C - Clerestory windows

GF - Ground Floor

N - North

PSS – Passive Solar Systems

RH – Relative Humidity

S - South

TAP - Thermosyphon Air Panel

W - West

LIST OF ILLUSTRATIONS

CHAPTER 2. DESIGN

Figures

Tables

CHAPTER 3. CONSTRUCTED BUILDING

Figures

Pictures

CHAPTER 4. OPERATION OF CONSTRUCTED BUILDING

Figures

Tables

CHAPTER 5. ANALYSIS – COMPUTER SIMULATION

Figures

Tables

CHAPTER 6. CONCLUSIONS

Figures

APPENDICES

Figures

Tables